Commodity Trade and the Carry Trade: A Tale of Two Countries*

Robert Ready[†], Nikolai Roussanov[‡] and Colin Ward[§]

April 3, 2015

Abstract

Persistent differences in interest rates across countries account for much of the profitability of currency carry trade strategies. The high-interest rate "investment" currencies tend to be "commodity currencies," while low interest rate "funding" currencies tend to belong to countries that export finished goods and import most of their commodities. We develop a general equilibrium model of international trade and currency pricing in which countries have an advantage in producing either basic input goods or final consumable goods. The model predicts that commodity-producing countries are insulated from global productivity shocks through a combination of trade frictions and domestic production, which forces the final goods producers to absorb the shocks. As a result, the commodity country currency is risky as it tends to depreciate in bad times, yet has higher interest rates on average due to lower precautionary demand, compared to the final-good producer. The carry trade risk premium increases in the degree of specialization, and the real exchange rate tracks relative technological productivity of the two countries. The model's predictions are strongly supported in the data.

*We benefited from comments by Andy Abel, Rui Albuquerque, Dave Backus, Gurdip Bakshi, John Campbell, Mike Chernov, Ric Colacito, Max Croce, Darrell Duffie, Bernard Dumas, Xavier Gabaix, Jeremy Graveline, Robin Greenwood, Tarek Hassan, Burton Hollifield, Urban Jermann, Karen Lewis, Debbie Lucas, Hanno Lustig, Don Keim, Brent Neiman, Anna Pavlova, Bryan Routledge, Jose Scheinkman, Ivan Shaliastovich, Ken Singleton, Rob Stambaugh, Andreas Stathopoulos, Sheridan Titman, Adrien Verdelhan, Jessica Wachter, Amir Yaron, Stan Zin, and audiences at the AFA and ASSA/IEFS meetings, CEPR ESSFM Gerzensee, Duke ERID macrofinance conference, Minnesota Asset Pricing conference, Oxford-MAN Currency Trading conference, NBER SI, NBIM, SECOR, Texas Finance Festival, SED, WFA, and Wharton. Roussanov acknowledges financial support from the Iwanowski Family Research Fellowship and Wharton Global Research Initiative.

[†]Simon School of Business, University of Rochester

[‡]The Wharton School, University of Pennsylvania, and NBER

[§]Carlson School of Management, University of Minnesota

1 Introduction

A currency carry trade is a strategy that goes long high interest rate currencies and short low interest rate currencies. A typical carry trade involves buying the Australian dollar, which for much of the last three decades earned a high interest rate, and funding the position with borrowing in the Japanese yen, thus paying an extremely low rate on the short leg. Such a strategy earns positive expected returns on average, and exhibits high Sharpe ratios despite its substantial volatility. In the absence of arbitrage this implies that the marginal utility of an investor whose consumption basket is denominated in yen is more volatile than that of an Australian consumer. Are there fundamental economic differences between countries that could give rise to such a heterogeneity in risk?

One source of differences across countries is the composition of their trade. Countries that specialize in exporting basic commodities, such as Australia or New Zealand, tend to have high interest rates. Conversely, countries that import most of the basic input goods and export finished consumption goods, such as Japan or Switzerland, have low interest rates on average. These differences in interest rates do not translate into the depreciation of "commodity currencies" on average; rather, they constitute positive average returns, giving rise to a carry trade-type strategy. In this paper we develop a theoretical model of this phenomenon, document that this empirical pattern is systematic and robust over the recent time period, and provide additional evidence in support of the model's predictions for the dynamics of carry trade strategies.

The fact that carry trade strategies typically earn positive average returns is a manifestation of the failure of the Uncovered Interest Parity (UIP) hypothesis, which is one of the major longstanding puzzles in international finance. A longstanding consensus in the international finance literature attributed all of the carry trade average returns to *conditional* risk premia, finding little evidence of non-zero *unconditional* risk premia on individual currencies throughout most of the twentieth century (e.g. see Lewis (1995)). Consequently, much of the literature has focused on explaining the conditional currency risk premia by ruling out asymmetries (e.g., Verdelhan (2010), Bansal and Shaliastovich (2012), Colacito and Croce (2012)). However, Lustig, Roussanov, and Verdelhan (2011) show that unconditional currency risk premia are in fact substantial; indeed, they account for between a third and a half of the profitability of carry trade strategies, Hassan and Mano (2014) provide evidence that carry trade profits are in fact primarily driven by unconditional differences in currency risk-premia across countries.[1] Lustig, Roussanov, and Verdelhan (2011) argue that these returns are compensation for global risk, and the presence of unconditional risk premia implies that there is persistent heterogeneity across countries' exposures to common shocks. In this paper we uncover a potential source of such heterogeneity.[2]

We show that the differences in average interest rates and risk exposures between countries that are net importers of basic commodities and commodity-exporting countries can be explained by appealing to a natural economic mechanism: trade costs.[3] We model trade costs by considering a simple model of the shipping industry. At any time the cost of transporting a unit of good from one country to the other depends on the aggregate shipping capacity available. While the capacity of the shipping sector adjusts over time to match the demand for transporting goods between countries, it does so slowly, due to gestation lags in the shipbuilding industry. In order to capture this intuition we assume marginal costs of shipping an extra unit of good is increasing - i.e., trade costs in our model are convex. Convex shipping costs imply that the sensitivity of the commodity country to world productivity shocks is lower than that of the country that specializes in producing the final consumption good, simply because it is costlier to deliver an extra unit of the consumption good to the commodity country in good times, but cheaper in bad times. Therefore, under complete financial markets, the commodity country's consumption is smoother than it would be in the

[1] See also Bakshi, Carr, and Wu (2008), Campbell, Medeiros, and Viceira (2010), Koijen, Pedersen, Moskowitz, and Vrugt (2012), and Lustig, Roussanov, and Verdelhan (2013) for additional empirical evidence. Theoretical models of Hassan (2013) and Martin (2011) relate currency risk premia to country size. Stathopoulos, Vedolin, and Mueller (2012) assume an exogenous source of heterogeneity in a multi-country model with habit formation.

[2] A number of patterns of heterogeneous risk exposures have been documented empirically. In a pioneering study, Lustig and Verdelhan (2007) show that carry trade risk premia line up with loadings on the U.S. aggregate consumption growth; Lustig, Roussanov, and Verdelhan (2011) and Menkhoff, Sarno, Schmeling, and Schrimpf (2012) link these risk premia to covariances with the global stock market and foreign exchange rate volatility shocks, respectively, while Lettau, Maggiori, and Weber (2013) show that high average return strategies in currency and commodity (as well as equity) markets perform particularly poorly during large U.S. stock market declines.

[3] Trade costs have a long tradition in international finance: e.g., Dumas (1992), Hollifield and Uppal (1997). Obstfeld and Rogoff (2001) argue that trade costs hold the key to resolving several major puzzles in international economics.

absence of trade frictions, and, conversely, the commodity importer's consumption is riskier. Since the commodity country faces less consumption risk, it has a lower precautionary saving demand and, consequently, a higher interest rate on average, compared to the country producing manufactured goods. Since the commodity currency is risky - it depreciates in bad times - it commands a risk premium. Therefore, the interest rate differential is not offset on average by exchange rate movements, giving rise to a carry trade.

We show empirically that sorting currencies into portfolios based on net exports of finished (manufactured) goods or basic commodities generates a substantial spread in average excess returns, which subsumes the unconditional (but not conditional) carry trade documented by Lustig, Roussanov, and Verdelhan (2011). Further, we show that aggregate consumption of commodity countries is less risky than that of finished goods producers, as our model predicts.

The model makes a number of additional predictions that are consistent with salient features of the data. Commodity-currency carry trade returns are positively correlated with commodity price changes, both in the model and in the data (we provide evidence using an aggregate commodity index, which complements the result obtained by Ferraro, Rossi, and Rogoff (2011) who use individual currency and commodity price data). Moreover, the model predicts that conditional expected returns on the commodity-currency carry trade are especially high when global goods markets are most segmented, i.e. when trade costs are particularly high. We show that a popular measure of shipping costs known as the Baltic Dry Index (BDI) forecasts unconditional carry trade returns (but not their conditional component). Our model also rationalizes the evidence of carry trade predictability with a commodity price index documented by Bakshi and Panayotov (2013), since commodity prices are typically high in the model during booms, when trade costs are also high.

2 Model

2.1 Setup

There are two countries each populated by a continuum of ex ante identical households endowed with time-separable preferences over the same consumption good. Both countries' representative households have CRRA preferences with identical coefficients of relative risk aversion γ and rates of time preference ρ. Time is continuous, and all households are infinitely-lived.

The countries are spatially separated so that transporting goods from one country to the other incurs trade costs, although we abstract from shipping costs for the basic commodity for tractability.[4] The "commodity country" has two production technologies available: one technology for producing the final (consumable) good; the other, for producing basic commodity which is an input required for production of the final good. The "producer country" only has one technology to produce the final good. Firms in both industries and in both countries are competitive.

The commodity country has a linear technology for producing the commodity that is either used domestically or exported to the producer country,

$$y_{ct} = z_{ct} l_{ct},$$

where l_c is a local non-traded input (this can be thought of labor or land) and z_c is its productivity.

The commodity country also has the final-good production function

$$y_{cpt} = z_{cpt}(y_{ct} - x_t)^{\alpha} l_{cpt}^{1-\alpha}, \tag{1}$$

where z_{cp} is a productivity level and x is the quantity of commodity exported, while l_{cp} is the local non-traded input. The latter is supplied inelastically in the amount of one unit, but is

[4] Although introducing such costs does not alter the main qualitative predictions of the model; see, Ready, Roussanov, and Ward (2013).

perfectly substitutable between the two sectors, so that $l_c + l_{cp} = 1$.

Since the producer country imports the commodity at no cost and there is only one production technology competing for the local resources, the same production function implies its output of the final good is given by

$$y_{pt} = z_{pt} x_t, \tag{2}$$

where z_p is its productivity level. We assume that the producer country has an absolute (as well as comparative) advantage in producing the final good:

$$z_{pt} > z_{ct} \text{ (almost surely).}$$

Given this assumption, in the absence of trade frictions it would be optimal for the two countries to specialize, so that the commodity country only produces the basic commodity and exports all of it to the producer country, where all production of the final good is concentrated. However, most commodity-producing countries do produce at least some of the goods they consume domestically, presumably because some of these goods are too costly to import from countries that produce them more efficiently, and in fact some consumption goods are entirely non-traded. We model such trade frictions by extending the classic variable iceberg cost of Backus, Kehoe, and Kydland (1992), where each unit of the final (consumable) good shipped from the producer country to the consumer country loses a fraction

$$\tau(X_t, z_{pt}) = \frac{\kappa}{2} \frac{X_t}{z_{pt}},$$

which depends on the total amount of goods exported from the producer country to the commodity country, X_t, and the productivity in the final-good producer country z_{pt}. The latter is meant to capture the dependence of trade frictions on the various short-run factors, such as available shipping capacity that cannot be adjusted quickly and is likely procyclical, as well as costs of financing trade that may be counter-cyclical.[5] The assumption that the

[5]Here shipping capacity is perfectly aligned with producer-country productivity. This assumption is not critical in generating the results: we relax it by allowing the two to be cointegrated in Ready, Roussanov, and

marginal cost of trade increases in the amount of exports is consistent with evidence on the various components of these costs. Hummels (2007) discusses evidence on evolution of trade costs over time and notes that despite a decline in freight costs actual trade costs may not decrease, for example as increasing amount of trade leads to greater congestion in ports, etc. Kalouptsidi (2014) and Greenwood and Hanson (2015) document substantial variation in freight costs due to gestation lags in the shipping sector and, consequently, global shipping capacity that is inelastic in the short run. Arkolakis (2010) shows that micro-level evidence is consistent with increasing marginal cost of exporting for individual firms.

The presence of trade frictions implies that the real exchange rate, i.e. the relative price of the same consumption bundle in the two countries, is not equal to unity. We denote this real exchange rate, expressed in the units of the producer country consumption basket per one unit of the commodity country consumption, by S_t.

Let p_t and p_t^* denote the price of the basic commodity in the units of the numeraire consumption good in the commodity and the producer countries, respectively. Since transporting the commodity between the two countries is costless, the law of one price holds, as the prices in the two countries are equated up to the exchange rate:

$$p_t = \frac{p_t^*}{S_t}. \tag{3}$$

2.2 Production

Given the structure of the production technologies, all firm decisions are static. Therefore, we can consider the intratemporal production decisions at a given point in time t without making specific assumptions on the dynamics of the exogenous state variables or considering the consumer problem. In this section we suppress all of the time subscripts for brevity.

Ward (2013). While we use "trade costs" and "shipping costs" interchangeably, in principle trade costs include a broader category of frictions than the monetary cost of freight. These could include the time delays due to port congestion, tariffs and non-tariff barriers to trade, and local distribution costs. More generally, this includes the idea that some goods are so prohibitively expensive to ship that they are essentially nontraded. An alternative would be to endow each country's consumers with a stronger preference for domestically produced consumption goods relative to foreign one, as used in international macroeconomics, e.g. by Backus, Kehoe, and Kydland (1994), and in the context of international asset pricing by, e.g., Pavlova and Rigobon (2007), Colacito and Croce (2010), and Stathopoulos (2011). We retain the classic BKK specification largely for tractability.

In each period, the commodity country firms in the commodity sector solve

$$\max_{l_c} pz_c l_c - wl_c \Rightarrow w = pz_c,$$

that must be satisfied for the price of local nontraded input w. The final-good sector firms solve

$$\max_{x,l_{cp}} z_{cp}(z_c l_c - x)^{\alpha} l_{cp}^{1-\alpha} - p(z_c l_c - x) - wl_{cp}$$

subject to the constraint that $l_c + l_{cp} = 1$. The first-order conditions of this problem imply that

$$\frac{\alpha}{1-\alpha} z_c l_{cp} = z_c l_c - x \tag{4}$$

$$\Rightarrow l_c = \alpha + (1-\alpha)\frac{x}{z_c}, \tag{5}$$

$$l_{cp} = (1-\alpha)\left(1 - \frac{x}{z_c}\right). \tag{6}$$

This implies that the fraction of labor directed to commodity production increases with the amount of commodity exports x. The maximum ($l_c = 1$) is reached when all of the commodity endowment is exported ($x = z_c$). The same set of necessary conditions (for an interior solution) imply that the price of the commodity in the commodity country is given by

$$p = \alpha z_{cp} \left(\frac{1-\alpha}{\alpha z_c}\right)^{1-\alpha}. \tag{7}$$

The commodity price p is a decreasing function of commodity endowment and an increasing function of the domestic final-good productivity. In particular, the combination of Cobb-Douglas and linear technologies imply that foreign demand for the commodity does not have a direct effect on the domestic price. However, it does determine the amount of the commodity exported to the producer country.

The producer country's final-good firm solves

$$\max_{x} z_p x - p^* x \tag{8}$$

$$\Rightarrow z_p = p^*. \tag{9}$$

Consequently, the goods-market no-arbitrage condition (3) implies a relationship between the real exchange rate and the relative productivities in the final-good sectors of the two countries:

$$S = \frac{p^*}{p} = \frac{z_p}{\alpha z_{cp}} \left(\frac{1-\alpha}{\alpha z_c} \right)^{\alpha - 1}, \tag{10}$$

which must be satisfied as long as both countries simultaneously use the commodity input to produce the final consumption good. In particular, the commodity currency appreciates in "good times" from the perspective of the final-good producer; that is, when its productivity improves (or when the commodity country's final-good productivity worsens).

2.3 Dynamics

We assume the shocks experienced by the producer country's final-good productivity are permanent, its evolution following a standard geometric Brownian motion:

$$\frac{dz_{pt}}{z_{pt}} = \mu dt + \sigma dB_t.$$

To ensure stationarity of the model, we assume the commodity country's productivity dz_{cpt} is cointegrated with the producer country's productivity and follows a general diffusion process. Its process is specified (explicitly in the Appendix) to ensure stationarity of the relative productivity:

$$z_t \doteq \frac{z_{cpt}}{z_{pt}}.$$

The assumption of comparative advantage requires $z_t < 1$; we further restrict its domain by requiring $z_t > \underline{z}$ for some $\underline{z} > 0$, so that the commodity country can always produce the final good. We assume that the relative productivity process follows a regulated Brownian motion

$$dz_t = \mu_{zt} dt + \sigma_z dB_{zt} - dU_t + dL_t,$$

where U_t and L_t are continuous, non-decreasing processes, and dB_{zt} is independent of dB_t. L_t only increases when $z_t = \underline{z}$ and U_t only increases when $z_t = 1$.[6] The resulting cointe-

[6] Regulated Brownian motions have been previously used in the international economics literature to model exchange rate dynamics in the presence of a target zone; see, Svensson (1991) and Froot and Obstfeld (1991).

gration relation can be interpreted as a reduced-form representation of an economy where both countries independently, and exogenously, innovate to improve their technologies that produce the final good, but the producer country always leads the commodity country in technological advancement. We set $\mu_{zt} = \sigma_z^2/z_t$. The specification of the drift can be thought of as having the commodity country adopt ideas and technologies from the producer country, thus allowing it to catch up in technological advancement, with the effect being greater during greater differences in relative productivity. In effect, the processes dz_{cpt} and dz_{pt} become more correlated when z_t nears one. This setup makes the relative ratio of productivities vary independently of the absolute level of productivity of the producer country, z_{pt}, which is a feature of the model that makes it particularly tractable.

Finally, we assume that the productivity in the commodity sector is constant, $z_{ct} = z_c$, so as to demonstrate clearly the role of the relative productivity in the final-good sector, as well as to make the model more tractable.[7] Under this assumption we can define a constant as a function of z_c, $\phi(z_c) = \alpha \left(\frac{1-\alpha}{\alpha z_c}\right)^{1-\alpha}$, so that the commodity price (in the units of the commodity country currency) is simply $p_t = \phi(z_c) z_{cpt}$.

2.4 Complete markets and consumption risk sharing

In order to emphasize that our mechanism does not rely on any financial market imperfections, we consider consumption allocations under complete markets. This is a standard benchmark in international finance, and is reasonable at least when applied to developed countries.[8] The main implications of our model do not hinge on the complete markets assumption, but the standard setting lends both transparency and tractability to the analysis.

Under complete markets, the equilibrium allocation is identical to that chosen by a central

We describe the process in more detail in the Appendix.

[7]More generally commodity supply can be modeled as a stochastic endowment cointegrated with global productivity (i.e., z_p). Such a cointegrated relationship can be interpreted as a reduced form representation of an economy where supply of the commodity is inelastic in the short run (based on the currently explored oil fields, say) but adjusts in the long run to meet the demand by the final-good producers (e.g., as new fields are explored more aggressively when oil prices are high). We solve a version of such model in Ready, Roussanov, and Ward (2013).

[8]For example, Fitzgerald (2012) estimates that risk-sharing via financial markets among developed countries is nearly optimal, while goods markets trade frictions are sizeable.

planner for a suitable choice of a (relative) Pareto weight λ. The planner's problem is

$$V(z_{pt}, z_{cpt}) = \max_{X_s} \mathbb{E}_t \left[\int_t^{\infty} e^{-\rho(s-t)} \left(\frac{c_{cs}^{1-\gamma} - 1}{1-\gamma} + \lambda \frac{c_{ps}^{1-\gamma} - 1}{1-\gamma} \right) ds \right],$$

where commodity-country consumption $c_{cs} = p_s(z_c - x_s) + X_s(1 - \frac{\kappa X_s}{2z_{ps}})$ and producer-country consumption $c_{ps} = z_{ps}x_s - X_s$, subject to the constraints (7) and (10) imposed by the production side of the economy (the latter are equivalent to including choice over x_s and l_{cs} in the planner problem, since firms act competitively). As before, because the production economy here is essentially static, the planning problem collapses to a sequence of one-period problems and we henceforth ignore time subscripts.

The first-order condition of the planner's problem, which holds state-by-state for all t, implies that

$$c_c^{-\gamma} \left(1 - \kappa \frac{X}{z_p} \right) - \lambda c_p^{-\gamma} = 0. \tag{11}$$

Since the real exchange rate (here defined in the units of the producer currency per one unit of the commodity currency) is the relative price of consumption in the two countries, it is proportional to the ratio of marginal utilities of the two countries' representative consumers:

$$S = \frac{1}{\lambda} \left(\frac{c_c}{c_p} \right)^{-\gamma}. \tag{12}$$

The combined equations (10) and (11) show how the exchange rate is jointly determined by the production and the consumption sides of the economy. Equation (10) states that the marginal product of the commodity is equated between the two countries, once expressed in the units of one of the country's currency (or consumption). Consequently, the real exchange rate must equal the ratio of the two countries' productivities (up to a constant):

$$S \propto \frac{1}{z}. \tag{13}$$

By using Ito's lemma for regulated processes (see Harrison (1985, p.82)), the dynamics of the exchange rate under $\mu_z = \frac{\sigma_z^2}{z}$ are

$$\frac{dS}{S} = -\frac{dz}{z} + \frac{dz^2}{z^2} = -\frac{z}{\underline{z}^2} dL + z dU - \frac{\sigma_z}{z} dB_z. \tag{14}$$

Our selection of the drift of the process z gives the model a nice feature, which is summarized in the next lemma (and proved in the Appendix).

Lemma 1 (Real exchange rate follows a martingale)**.** *If* $\mu_{zt} = \sigma_z^2/z_t$ *then the growth of the real exchange rate is a martingale:*

$$\mathbb{E}_t\left[\frac{dS}{S}\right] = 0.$$

Indeed, that the real exchange rate follows a martingale is consistent with empirical evidence that exchange rate changes are essentially unforecastable (see, e.g. Adler and Lehmann (1983), Meese and Rogoff (1983)).

Equation (11) states that the relative value of the consumption good in two countries is equated up to the marginal cost of transporting it from the producer country to the commodity country. Consequently, the real exchange rate is proportional to the marginal value of one unit of the final good that has been transported from the producer to the commodity country, as is generally the case in one-good models with trade costs (e.g., see Dumas (1992), Hollifield and Uppal (1997), Verdelhan (2010)):

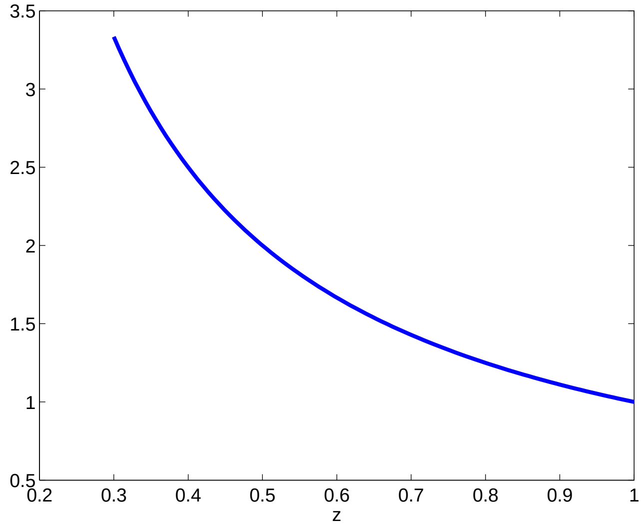
$$S = \frac{1}{\left(1 - \kappa\frac{X}{z_p}\right)}. \tag{15}$$

The first-order condition in (11) combined with the law of one price for commodities in (10) gives an explicit solution for final-good exports X:

$$X = \left(1 - \frac{p}{z_p}\right)\frac{z_p}{\kappa} = \frac{1}{\kappa}\left(z_p - \phi(z_c)z_{cp}\right). \tag{16}$$

This expression is very intuitive: it shows that exports of the final good are increasing (linearly) in the producer-country labor productivity, and decreasing in the final-good productivity in the commodity country. The trade cost scales down final good exports and therefore drives a wedge between the two countries' consumptions. The magnitude of this wedge depends on the relative productivity of final-good production, z, and using the first-

Figure 1: Consumption wedge



order conditions we can formally define this consumption wedge

$$\omega(z) \doteq \frac{c_p}{c_c} = \left(\frac{1-\kappa\frac{X}{z_p}}{\lambda}\right)^{-\frac{1}{\gamma}} = \left(\frac{p}{\lambda z_p}\right)^{-\frac{1}{\gamma}} = \left(\frac{\phi(z_c)}{\lambda}z\right)^{-\frac{1}{\gamma}}. \tag{17}$$

The consumption wedge measures the extent to which the producer country bears a larger share of aggregate consumption and also the risk associated with it. Because in equilibrium the producer country's consumption will be a nonlinear, scaled version of the commodity-country's consumption, the producer country will have a relatively more variable consumption stream. On average, if long-run consumption growth rates are equal between the two countries, greater demand for precautionary savings will lead the producer country to have a relatively lower risk-free rate.

A related comment is that because the real exchange rate is positively related to the consumption wedge, $S = \frac{1}{\lambda}\omega(z)^{\gamma}$, the real exchange will comove positively with it and thus will depreciate in "bad times" for the producer country, when its relative aggregate consumption share declines.

Solving for equilibrium commodity exports x gives

$$x\left(z_p, z\right) = \frac{p z_c \omega(z) + X + X\left(1 - \frac{\kappa}{2}\frac{X}{z_p}\right)\omega(z)}{z_p + p\omega(z)},$$

which can be used to compute the consumption allocations:

$$c_c = z_p \frac{z_c \phi(z_c) z + \frac{1}{2\kappa}\left(1 - \phi(z_c) z\right)^2}{1 + \omega(z)\phi(z_c) z} \tag{18}$$

and

$$c_p = \omega(z) c_c.$$

Commodity country consumption c_c comes from two sources: the first is domestic production of the final good, while the second consists of imports of the final good from the producer country. When z decreases, the main source of consumption for the commodity country shifts from domestic production to imports. Additionally, the consumption wedge increases, as the producer country bears an increasingly greater share of aggregate risk. This widening of the consumption wedge can be seen as a simple form of the "Dutch Disease": as the 'world' price of the commodity rises, driven by the increase in foreign productivity relative to its domestic level, commodity production and exports crowd out domestic production; however, trade frictions imply that the rising imports of consumption goods are not sufficient to compensate for the decline in local production for domestic consumers.

Conversely, as z increases towards its upper limit of unity, commodity exports x decline, raising domestic production of the final good in the commodity country and shrinking the consumption wedge. We rely on the following lemma and discuss its proof in the Appendix:

Lemma 2. *There exists a fixed point $z_c^* = H(z_c^*)$ given parameters $\alpha, \lambda, \kappa, \gamma$, and $\underset{\sim}{z}$ where*

$$H(z_c^*) \doteq \max_{z_c} \frac{1}{\kappa}\left(1 - \phi(z_c)\underset{\sim}{z}\right)\left(1 + \frac{1}{2}\left(1 + \phi(z_c)\underset{\sim}{z}\right)\left(\frac{\phi(z_c)}{\lambda}\underset{\sim}{z}\right)^{-\frac{1}{\gamma}}\right).$$

And therefore $x\left(z_p, z\right) \leq z_c^*$ for all $z_p > 0$ and all $z \in (\underset{\sim}{z}, 1)$.

Thus the commodity-export ratio x/z_c is always less than or equal to one. Furthermore, we hereon restrict attention to cases where $z_c > z_c^*$ and will simply then define a constant ϕ^* as a member of this set of satisfactory constants: $\phi^* \in \{\phi(z_c)|z_c > z_c^*\}$. With this restriction we have $x < z_c$ always and $\phi^* < 1$.

2.5 Import ratios

While our model features complete specialization, in the sense that each country only exports one type of good, the degree to which a country is an importer of final goods and an exporter of commodities, and vice versa, relative to its output, varies over time. This degree can be quantified by measuring imports of the two types of goods relative to output, with the view towards testing model's predictions in empirical work. Define the import ratio for a given country as

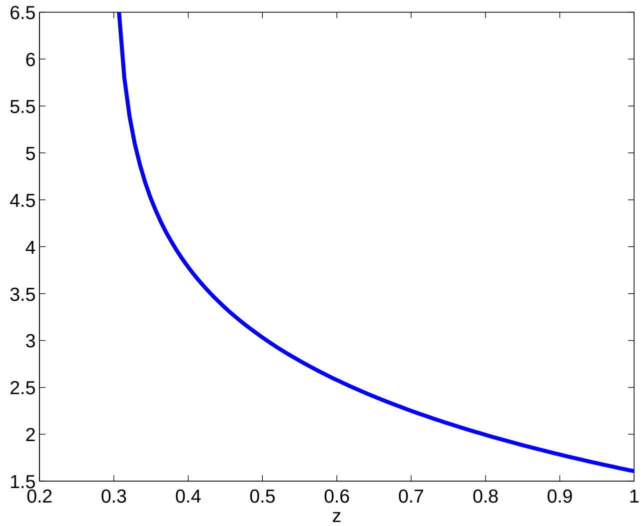
$$\frac{\text{Net Imports of Finished Goods} + \text{Net Exports of Basic Goods}}{\text{Output}}.$$

where we normalize the trade quantities in the numerator by consumption here, then we have the following:

- Commodity-country import ratio: $IR_c \doteq \frac{XS+xpS}{y_{cp}S}$
- Producer-country import ratio: $IR_p \doteq -\left(\frac{X+xpS}{y_p}\right)$

The spread of the log of these ratios $(IR_c - IR_p)$ is plotted in Figure 6. The ratios do not converge to zero when z approaches one because the producer country needs to import the commodity to have positive consumption. This ratio is an easily measurable empirical quantity. As a country becomes relatively more efficient at producing the final good, it becomes a net exporter of final goods, and has a lower and possibly even negative import ratio. On the other hand, as a country becomes more efficient at producing commodities, relative to its production capabilities of producing the final good, its import ratio rises. The spread between the two country's import ratios acts as a measure of relative productivity and comparative advantage, which in turn is a measure of the degree to which the country with the lower import ratio bears aggregate risk.

Figure 2: Import ratio spread: $\log(IR_c - IR_p)$



It follows from our definitions of final-good outputs in (1) and (2), equation (3), and the first-order condition in (5) that global output in units of the producer country's final good equals $Y = z_p z_c$. Consequently, z has no effect on this quantity, only its spatial distribution of output across countries. However, countries' productivities and industrial outputs co-move differently with global output, as shown in the following Lemma.

Lemma 3. *The change in productivity of the producer country covaries more with the change in global output, $Y = z_p z_c$, than does the commodity country's change:*

$$\mathbb{E}_t \left[dz_p \cdot dY \right] = \sigma^2 z_p^2 z_c dt > z\sigma^2 z_p^2 z_c dt = \mathbb{E}_t \left[dz_{cp} \cdot dY \right]$$

Because global final-good output is determined relatively more by the producer country, as it has greater final-good productivity, its productivity is naturally going to be more correlated with global output. We relegate the discussion on the empirical support of this prediction to Section 3.3.

2.6 Asset pricing implications

The definition of stochastic discount factor (SDF) for the producer country is standard and with an application of Ito's lemma for regulated processes has the dynamics

$$\frac{d\pi_p}{\pi_p} = -\rho dt - \gamma \frac{dc_p}{c_p} + \frac{1}{2}\gamma(1+\gamma)\frac{dc_p^2}{c_p^2} - \gamma \frac{1}{c_p} dL + \gamma \frac{1}{c_p} dU,$$

where the terms of dL and dU will be referred to in what follows as the "regulator terms".

The commodity country's SDF follows from our complete markets assumption, which allows it to be usefully rewritten in terms of S and c_p.

$$\pi_c = e^{-\rho t} c_c^{-\gamma} = e^{-\rho t} \left(\frac{c_p}{\omega(z)} \right)^{-\gamma} = e^{-\rho t} c_p^{-\gamma} S \lambda$$

$$\Rightarrow \frac{d\pi_c}{\pi_c} = -\rho dt + \frac{dS}{S} - \gamma \frac{dc_p}{c_p} + \frac{1}{2}\gamma(1+\gamma)\frac{dc_p^2}{c_p^2} - \gamma \frac{dS}{S}\frac{dc_p}{c_p} - \gamma \frac{1}{c_p} dL + \gamma \frac{1}{c_p} dU,$$

where we suppressed the regulator terms of dS/S as they appear in (14) and exploited the relationship $S\lambda\pi_p = \pi_c$.

Noting that the producer-country consumption regulator terms conveniently cancel out when differencing, the interest rate differential between the two countries is then given by

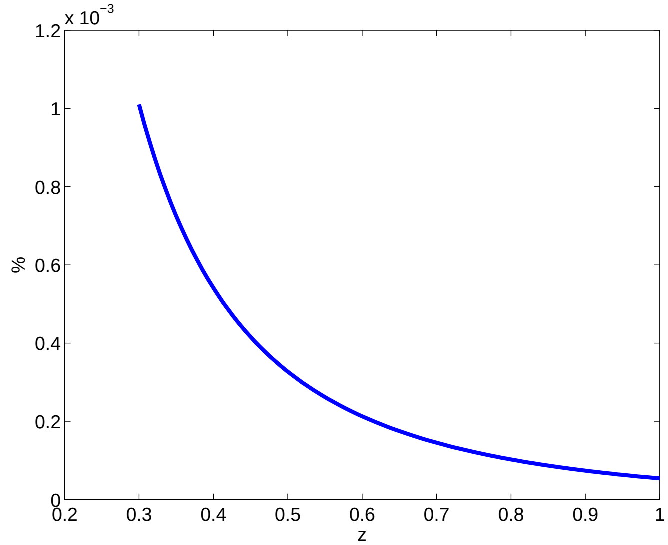
$$(r_c^f - r_p^f)dt = -\mathbb{E}_t \left[\frac{d\pi_c}{\pi_c} \right] + \mathbb{E}_t \left[\frac{d\pi_p}{\pi_p} \right] = -\mathbb{E}_t \left[\frac{dS}{S} \right] + \gamma \mathbb{E}_t \left[\frac{dS}{S} \frac{dc_p}{c_p} \right], \tag{19}$$

where the first term is the expected depreciation of the commodity currency and the second term is the risk premium. The latter equation can be written as

$$(r_c^f - r_p^f)dt + \mathbb{E}_t \left[\frac{dS}{S} \right] = \underbrace{\gamma \mathbb{E}_t \left[\frac{dS}{S} \frac{dc_p}{c_p} \right]}_{\text{Risk premium}}$$

Because the real exchange rate follows a martingale, the risk premium simply equals the interest rate differential, and, aside from the specification of standard CRRA preferences, is

Figure 3: Carry trade risk premium



independent of the other features of the model. The risk premium is given by

$$\gamma \mathbb{E}_t \left[\frac{dS}{S} \frac{dc_p}{c_p} \right] = \gamma \sigma_z^2 \frac{1}{z^2} \left[\frac{\frac{1}{2\kappa}(1-\phi^* z)^2}{z_c \phi^* z + \frac{1}{2\kappa}(1-\phi^* z)^2} \frac{(1+\phi^* z)}{1-\phi^* z} - \frac{1-\frac{1}{\gamma}}{1+\phi^* z \omega(z)} \right] dt. \qquad (20)$$

In the special case of log utility, the risk premium, interest rate differential, and difference in the import ratio, can be signed analytically.

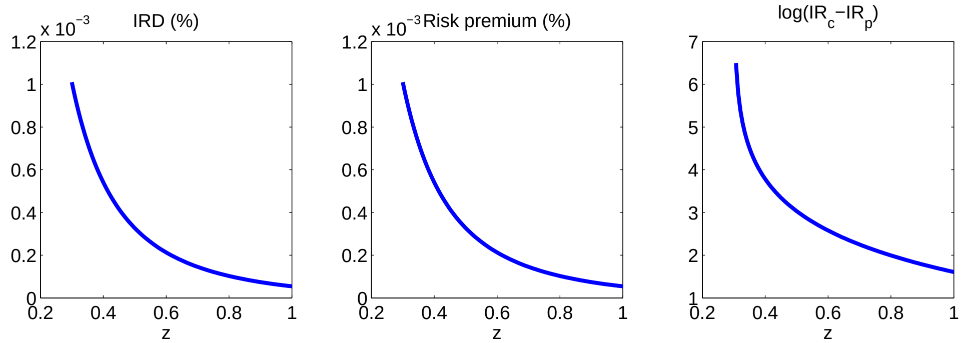
Proposition 1 (Risk premium, interest rate differential and import ratio)**.** *If the conditions of Lemma 2 above are satisfied and $\gamma = 1$, then*

1. *the risk premium and the interest rate differential are positive for all z*
2. *the spread of the import ratios $\Delta IR \doteq IR_c - IR_p$ is decreasing in z*
3. *if $\alpha \in [0, 0.8651)$ and $z_c > \max\{\frac{2}{\sqrt{5}-1}, z_c^*\}$, then the risk premium and the interest rate differential are decreasing in z. Thus, the spread between the import ratios is positively related to the currency risk premium and the interest rate differential.*

The conditions required for the positivity of the risk premium, in addition to log utility, simply ensure that some quantity of the basic commodity is always retained to be used as input in domestic production in the commodity country. The second is a technical condition that is easily satisfied for reasonable parameter values: (i) a Cobb-Douglas labor share in final-good production over 0.1349 and (ii) a large enough quantity of commodity production to satisfy Lemma 1 or a simple value of $\frac{2}{\sqrt{5}-1}$.[9]

Both the interest rate differential and the risk premium are closely related to the import ratio. Figure 4 demonstrates that both are increasing as z falls, while the dispersion between the two countries' import ratios rises. Therefore, the behavior of the *conditional* currency risk premia can be captured by the dispersion between the import ratios of the commodity country and producer country.

Figure 4: Relationship between interest-rate differential, risk premium, and import ratio



The risk premium is increasing in the consumption wedge, which captures the degree of endogenous risk sharing between the two countries. Risk sharing is weakest when the trade costs are high and, consequently, the consumption wedge is large. Figure 5 plots the currency risk premium against the average trade cost, illustrating the strong monotonic relationship between the two: high trade costs imply a high risk premium.

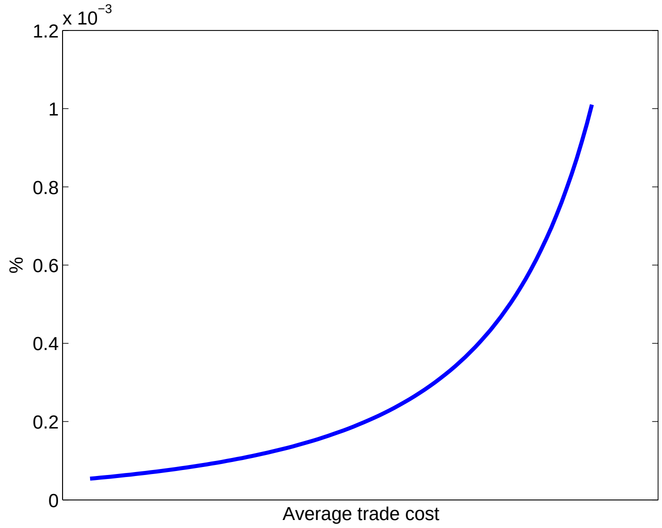
2.7 Summary of implications

The qualitative implications of the above proposition can be summarized as a set of predictions for the risk and return properties of exchange rates.

1. The final-good-producing country bears more aggregate risk. Therefore, it has a larger precautionary demand and lower interest rates, on average, than the commodity-producing country. (Proposition 1)

[9]These conditions are described in the Appendix.

Figure 5: Carry trade risk premium



2. The commodity earns a risk premium, giving rise to a carry trade. (Proposition 1)

3. The interest rate differential and the commodity currency risk premium are both increasing in spread between the import ratios of the two countries. (Proposition 1)

4. The change in the productivity of the producer country is more correlated with global output than is the commodity country's. (Lemma 3)

5. Real exchange rates and interest rate differentials between commodity and producer country currencies are proportional to the ratio of productivities in the countries' final goods producing sectors. (Equation 12)

6. A widening of the productivity wedge between the producer country and the commodity country implies high shipping costs and a lower degree of international risk sharing. Therefore conditional expected carry trade returns are positively correlated with trade costs. (Proposition 1 and Equation 16)

Our model of exchange rate determination is deliberately simple and meant to highlight the mechanism leading to a carry trade: specialization combined with non-linear shipping costs. The model nevertheless makes a rich set of qualitative predictions, which we now evaluate empirically.

2.8 Discussion of implications

In deriving the model's implications described above we rely on the assumption of complete markets for tractability. This assumption is admittedly extreme, and is likely to lead to counterfactual predictions, in particular regarding the behavior of aggregate consumption growth. In particular, one of the classic puzzles of international finance going back to Backus and Smith (1993) is the fact that differences betwen countries' consumption growth rates tend to be only weakly correlated with real exchange rate changes, and often with the wrong sign. This puzzle does not in itself invalidate our model's mechanism: it is relatively standard in the literature to depart from the assumption of complete markets by considering economies with limited participation, where some but not all households share risks internationally while other "inactive" households do not participate in financial markets at all - e.g. Alvarez, Atkeson, and Kehoe (2002), Hassan (2013), and Ramanarayanan and Cociuba (2011). In particular, Hassan (2013) shows that the interest rate differentials that translate into risk premia due to differences in countries' effective consumption risk generalize to such a segmented market economy where only the "active" investors' consumption matters for risk premia.[10] There is no reason to expect that such an argument would not carry over to our setting, albeit at a cost of substantially reduced tractability.

The key prediction - that the commodity country currency is riskier - follows directly from the goods-market no-arbitrage condition (3) and the fact that the producer country productivity is more important for global output (and therefore consumption). However, predictions about relative volatility of *aggregate* consumption growth are likely to be more sensitive to market structure. In particular, they are likely to be especially counterfactual for the cases of emerging commodity countries, which are likely to be far from the complete markets benchmark as few they are not sufficiently financially developed to allow a large fraction of consumers to share risk internationally. In fact, this conforms with a standard intuition that (developing) commodity countries are "riskier" - this may be the case if terms of trade are sufficiently volatile and markets sufficiently segmented to allow for very little insurance.

[10]Alternatively, the Backus-Smith puzzle could be resolved within the representative-agent setting under non-separable preferences (e.g., Colacito and Croce (2011), Stathopoulos (2011)).

Consequently, we do not emphasize the model's predictions regarding aggregate consumption volatility in what follows and instead focus on the role of relative productivity. This may be particularly important when considering emerging countries, since they are the least likely to exhibit a high degree of international risk sharing due to limited financial development stemming from the lack of sufficient investor protection, capital controls, and other barriers to financial trade. In fact, emerging commodity countries are often thought of as exposed to more (rather than less) risk precisely because they are unable to buffer terms of trade shocks via trade in financial claims in the way that more developed countries might (e.g., Norway).

Relative productivity is an important object in international economics. In fact, our model's relation between the productivity differential and the real exchange rate resembles the classic Balassa-Samuelson effect, which is a statement that the relative price of nontraded (or relatively less traded) goods and, therefore, real exchange rate, is higher for the countries with higher labor productivity. This effect relies on the existence of a perfectly traded good and perfectly elastic substitution of labor between sectors. In the context of our model the basic commodity is the freely traded good and the commodity country always has the advantage at producing it, but labor productivity differs across sectors. Nevertheless, the Balassa-Samuelson effect can still be seen at work in the sense that the commodity country's price of the final consumption good is always higher than in the producer country, since it is more costly to either produce it in or import it into the commodity country (and consequently marginal utility of consumption is higher). The effect of labor productivity is the reverse of that in the Balassa-Samuelson hypothesis because it is allowed to vary across sectors, so that when productivity in the final good sector rises in the commodity country it actually shifts labor out of the more productive export sector and into the (less traded) consumption good, lowering its price and therefore the real exchange rate. The potential role of differences in labor productivity across sectors that are highlighted in our model could be one of the reasons why empirical evidence for the Balassa-Samuelson effect is somewhat mixed (e.g. see Rogoff (1996) and references therein).

Since our model features a single consumable good and a cost to transporting this good between countries it shares some elements with the classic models of international finances such as Dumas (1992). In these models exchange rates vary in a region where no trade occurs due to the proportional trade cost, driven by shocks to capital productivities in the (ex ante symmetric) countries. The less productive country (importing the good) has a higher interest rate and its currency earns a positive risk premium, but the bulk of the interest rate differential is driven by the expected currency depreciation while the risk premium is generally small and behaves highly nonlinearly. In fact Hollifield and Uppal (1997) show that a model of this class cannot satisfy the Fama (1984) condition that the volatility of the currency risk premium must be larger than the volatility of expected currency depreciation in order to reproduce the forward premium puzzle. This condition is satisfied trivially in our model since the real exchange rate is a martingale, and consequently the risk premium accounts for the entirety of the interest rate differential.

3 Empirical evidence

3.1 Data

Following Lustig, Roussanov, and Verdelhan (2011) we use forward and spot exchange rates to construct forward discounts (approximately equal to the interest rate differentials by the covered interest parity relation) and excess returns on currencies. Denoting log forward exchange rate one month ahead $f_t = logF_t$ and log spot exchange rate $s_t = logS_t$, both expressed in units of foreign currency per one U.S. dollar, the forward discount is equal to the interest rate differential: $f_t - s_t \approx i_t^\star - i_t$, where $i^\star$ and i denote the foreign and domestic nominal one month risk-free rates.

The log excess return rx on buying a foreign currency in the forward market and then selling it in the spot market after one month is then given by

$$rx_{t+1} = f_t - s_{t+1},$$

while the arithmetic excess return is given by

$$Rx_{t+1} = \frac{F_t}{S_{t+1}} - 1.$$

Data is provided by Barclays and Reuters and is available via Datastream. We use monthly series from February 1988 to April 2013.[11]

We use two samples in our analysis. The sample of all 35 developed and emerging countries includes: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Euro area, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, United Kingdom. The sub-sample of 21 developed-country currencies includes: Australia, Austria, Belgium, Canada, Denmark, Euro, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

3.2 Unconditional Average Excess Returns

Table 1 shows U.S. dollar average returns and forward discounts on the nine most actively traded currencies, collectively known as the G10 countries (the tenth currency being the U.S. dollar itself), over our sample period. Following Lustig, Roussanov, and Verdelhan (2011), we compute the average forward discount prior to 1995 and the returns after 1995. The German Deutschmark forward discount and the excess return to investing in Deutschmark forward contracts prior to 1999 are spliced with the euro variables post-1999. The table is sorted from low average returns to high average returns. What is immediately apparent is that the high return countries tended to have unconditionally high forward discounts, consistent with the unconditional carry trade strategy documented in Lustig, Roussanov, and Verdelhan (2011).

Interestingly, this relation between average forward discounts and excess returns is not a perfectly monotonic one, in that some low return countries have high discounts. This is not necessarily surprising since factors other than expected returns (e.g. expected inflation) can

[11] While Lustig, Roussanov, and Verdelhan (2011) start their sample in 1983, very few currencies have forward discounts available in the first few years of the sample, as a number of countries, including Australia and New Zealand, undergo transition from fixed to floating exchange rates during this period. The latter countries have forward discounts available starting in 1985, but these display patterns suggesting episodes of extreme illiquidity, such as large bid-ask spreads and violations of covered interest parity relation (CIP) before 1988. Finally, the Plaza Accord of September 22, 1985 led to a large but gradual appreciation of the Deutschmark, the French Franc, and the Japanese Yen over the course of 1986 and 1987. Since these movements were largely predictable by investors it appears natural to consider unconditional strategies including these currencies starting in 1988.

Table 1: **G10 Currency Average FX Returns and Discounts**

Country	Excess Return	Forward Discount
Japan	-1.97	-2.70
Switzerland	-0.32	-1.53
Germany/Euro	0.11	-0.15
Sweden	0.80	1.37
United Kingdom	0.92	1.81
Canada	1.66	0.65
Norway	1.99	1.81
Australia	4.02	2.71
New Zealand	4.06	3.08

Average annualized forward discounts prior to 1995 and and excess returns (without accounting for transaction costs) after 1995 for the "G-10" currencies from the perspective of a U.S. dollar investor. Germany/Euro is calculated based on the German Deutschmark prior to 1999 and the Euro post 1999. Data are monthly forward contracts from 1988 to 2012 available via Datastream.

have an effect on nominal interest rates, and therefore forward discounts.[12] It is clear, however, that the countries with low returns tend to be countries with advanced manufacturing economies which are also relatively resource poor. Indeed, the entire top half of the table: Germany, Japan, Sweden, Switzerland, and the UK all fit this description to some degree. In contrast, the high return countries on the bottom half of the table tend to be large exporters of either oil (Canada and Norway) or other base agricultural or mineral commodities (New Zealand and Australia).

3.3 Import Ratios, Interest Rates, and Currency Excess Returns

In order to classify countries based on their exports we utilize the U.N. COMTRADE database of international trade flows. We use the NBER extract version of this data, available for years 1980-2000, we augment it with the original COMTRADE data for years 2001-2012 following the same methodology. The two goods in the model are a basic good, which is used as an input in production, and a final good, which is used in consumption. While this suggests

[12] Pairwise average currency returns are only marginally statistically different from zero due to the substantial noise in bilateral exchange rate movements, consistent with evidence in Bakshi and Panayotov (2013); however, aggregating currencies into portfolios (e.g., long bottom four, short top four) reduces idiosyncratic noise and ensures robustly statistically significant average returns (as detailed in Data Appendix Table A-1).

a potential classification of goods as either "input" or "final" goods, there are many goods for which this classification struggles to conform to the intuition of the model. The important mechanism in the model hinges on the extra trade costs associated with shipping complex produced goods back to the commodity exporter rather than the specific use of the goods as consumption or input. For instance, New Zealand is a large exporter of many agricultural commodities, some of which (such as butter) are in their final consumable form. Likewise, New Zealand imports a large amount of sophisticated construction equipment which is produced using basic commodities (e.g., metals, energy) as an input. However, in the context of the model, a complex piece of construction equipment seems more closely related to the final good rather than the basic good, while butter is a better representation of the basic good. Moreover, the specialization assumption in the model implies that the production process in the producer country cannot be easily replicated in the commodity country, suggesting a high level of complexity for the final good. Therefore to be consistent with the model mechanism we classify goods as a basic good (i.e. a commodity) or a complex manufacturing good based on their 4-digit SITC codes. The classifications at the 2-digit level are in the appendix (Table A-2), and the full classification is available upon request.

In order to test the model's predictions we use this classification of goods and construct the empirical measure of the Import Ratio defined in Section 2.5:

$$\frac{\text{Net Imports of Complex Goods} + \text{Net Exports of Basic Goods}}{\text{Manufacturing Output}},$$

where manufacturing output is the total output in the sector that produces complex goods. As an empirical counterpart of this output we use the value added from manufacturing of "Machinery and Transport Equipment" from the U.N.'s, International Yearbook of Industrial Statistics.

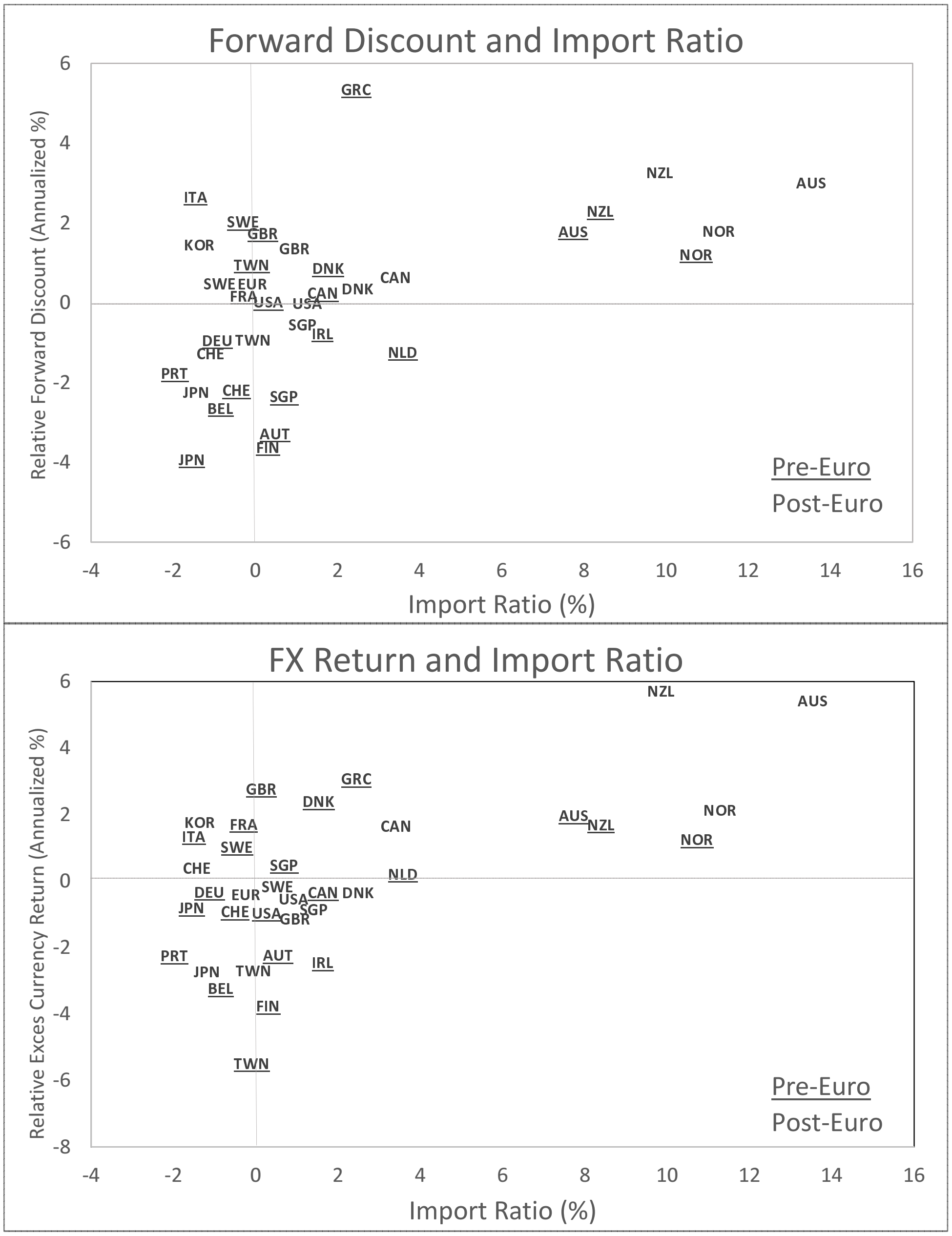
This measure captures the extent to which a country specializes in the production of basic commodities, as well as the extent to which a country imports complex goods. Moreover, to the extent a country's changing composition of output and trade over time reflects its fluctuations in productivity this measure should also capture the variation in the country's productivity relative to that of its trade partners.

To test the first two implications of the model, we first examine how interest rates and currency risk premiums relates to import ratios in our cross-section of currencies. Figure 6 plots the average forward returns and discounts against the average import ratio for each country over both the Pre- and Post-Euro samples. For this figure, forward discounts and currency returns are calculated from the perspective of the US investor. In order to focus on cross-sectional differences in countries as opposed to time series changes, the per-period averages of country discounts and returns are subtracted. As the first plot shows, there is a clear relation between the import ratio and average forward discounts. Commodity countries are generally high interest rate countries, consistent with the predictions of the model. The second plot shows a similar pattern in returns, with the commodity countries earning higher returns than producer countries, again consistent with the model. Notably, the U.S. is an average country in terms of its trade composition, and also an average country in terms of forward discounts and returns.

To test for statistical significance of these relations, Table 2 presents cross-sectional regression evidence that relates our import/export composition variable to the excess currency returns and forward discounts. Panel A presents results for the full sample of countries (IMF Advanced Economies) while Panel B presents the results for the G10 currencies. The left hand side of each panel presents estimates from Fama-MacBeth regressions of monthly currency excess returns on the import ratios. The right hand side of each panel presents estimates from Fama-Macbeth regressions of monthly forward discounts on import ratios. Standard errors are Newey-West with 36 months of lags to account for time-series persistence in the dependent variables.

As evidenced by the regression slope coefficients, the import ratio is a strong positive predictor of future excess returns, and is strongly correlated with contemporaneous forward discounts. As indicated by the R^2 of this regression, our trade-based variable explains a substantial portion of the cross-sectional variation in the average interest rate differentials across countries, as well as in average returns. This variation is clearly not driven entirely by country size as suggested by Hassan (2013), since the U.S. as well as the U.K. are in the middle of the distribution of the import/export variable (as well as of the average forward discount, which equals zero for the U.S. by construction). Controlling for the logarithm of

Figure 6: Import Ratios vs. Forward Discounts and FX Returns



This figure plots forward discounts and excess FX returns against the import ratio for each country in our IMF Advanced Economies sample. The import ratio is calculated as

$$\frac{\text{Net Imports of Complex Goods} + \text{Net Exports of Basic Goods}}{\text{Manufacturing Output}},$$

Both forward discounts and FX returns are calculated from the perspective of a U.S. investor. Underlined observations are the averages for the Pre Euro period and non-underlined observations are the average of the Post Euro period. For each period both average returns and discounts are adjusted by subtracting the period mean for all countries.

country GDP in a manner similar to Hassan (2013) shows a relation between country size and currency risk premia subsumed by the import ratios in the full sample. In the G10 country sample both variables are significant. Controlling for a lagged 3-year rolling average of log CPI changes as a measure of inflation forecast weakens somewhat the predictive power of the import ratio for the cross-section of average returns, but does not eliminate it, and inflation itself does not seem to predict future excess returns. Inflation is strongly related to forward discounts, but its inclusion leaves the coefficients on the import ratio largely unchanged and highly significant for the full sample. While the power is reduced for the G10 sample, the import ratio remains significant in all cases. This evidence is consistent with the model's prediction that the import ratio contains relevant information about the real interest rate differential and currency risk premia. For countries that experienced high inflation for a sustained period of time in our sample forward discounts are less informative about risk premia since they are dominated by expected inflation, which on average translates into depreciation of the high-yielding currency (e.g., Bansal and Dahlquist (2000)).

3.4 Import and Ratios and Exposure to Global Output

Having shown that the implications of the model regarding interest rates and currency returns are strongly supported by the data, we now turn to the mechanism of the model. The basic intuition of the model lies in the fact that producer countries are by their nature more exposed to changes in global output, and that they imperfectly share this risk with commodity countries. To test the implication that changes in producer country covary more strongly with changes in global output, we regress growth in country productivity for the OECD countries in our sample against growth in total OECD output. As a proxy for productivty we use the index of real labor productivity from the OECD. Figure 7 shows slope coefficients of these regressions plotted against the Import Ratio of each country. As the figure shows, commodity countries such as Australia, New Zealand, and Norway have much lower exposure to changes in global output. Across the sample of OECD countries this relation is strongly significant, suggesting that commodity country output is indeed less important for the global real business cycle than producer country output. Notably, the USA is an average country by this measure as well, suggesting again that this result is not mechanically driven by country

Table 2: Cross-Sectional Regressions of FX Returns and Forward Discounts

Panel A: IMF Advanced Economies

	Fama-Macbeth Regressios of FX Returns					Fama-Macbeth Regressions of Forward Discounts				
VARIABLES	FX Ret	FX Ret	FX Ret	FX Ret	FX Ret	Fwd Dsct	Fwd Dsct	Fwd Dsct	Fwd Dsct	Fwd Dsct
Import Ratio	0.29*		0.25*	0.25*	0.20+	0.23**		0.23**	0.14**	0.13**
	(0.12)		(0.12)	(0.12)	(0.11)	(0.03)		(0.04)	(0.03)	(0.03)
Log GDP		-0.65**	-0.33		-0.29		-0.30**	-0.03		-0.04
		(0.25)	(0.20)		(0.21)		(0.04)	(0.06)		(0.04)
Inflation				0.22	0.20				0.29**	0.30**
				(0.21)	(0.22)				(0.04)	(0.04)
Constant	0.65	10.25*	5.17	-0.08	4.03	0.04	4.51**	0.36	-1.75**	-1.17
	(1.31)	(4.31)	(3.69)	(2.25)	(4.18)	(0.50)	(0.57)	(1.04)	(0.62)	(0.92)
Obs	4,542	4,542	4,542	4,542	4,542	4,550	4,550	4,550	4,550	4,550
R-squared	0.13	0.07	0.18	0.22	0.26	0.27	0.05	0.29	0.49	0.51
Number of Months	304	304	304	304	304	304	304	304	304	304

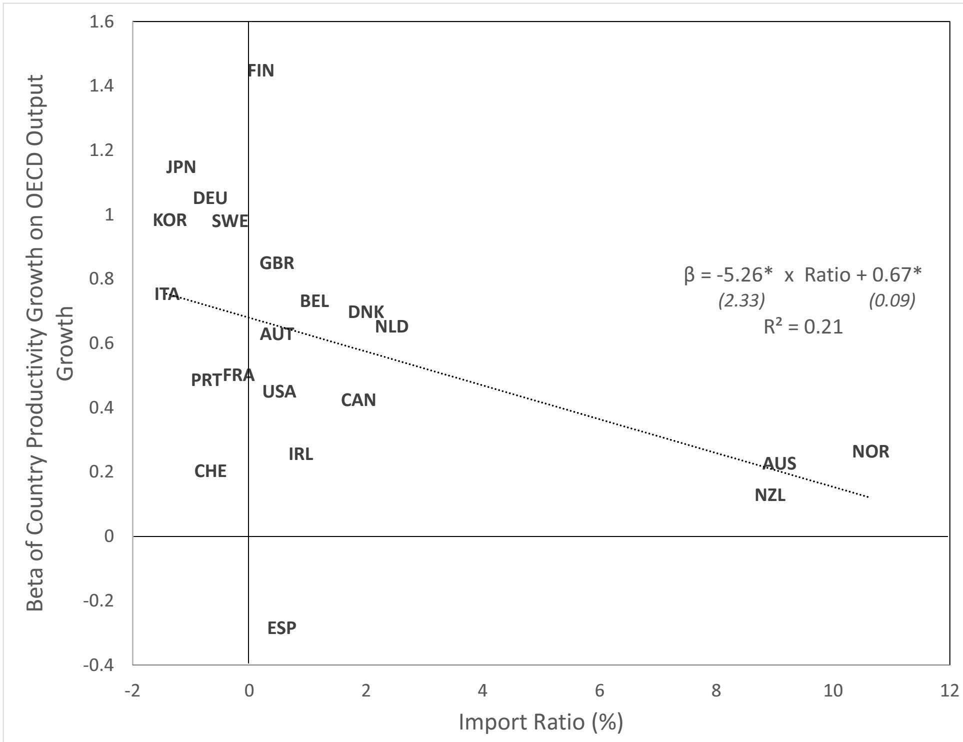
Panel B: G10 Currencies

	Fama-Macbeth Regressios of FX Returns					Fama-Macbeth Regressions of Forward Discounts				
VARIABLES	FX Ret	FX Ret	FX Ret	FX Ret	FX Ret	Fwd Dsct	Fwd Dsct	Fwd Dsct	Fwd Dsct	Fwd Dsct
Import Ratio	0.31*		0.24*	0.33**	0.20+	0.27**		0.21**	0.14**	0.07+
	(0.13)		(0.12)	(0.13)	(0.11)	(0.03)		(0.05)	(0.04)	(0.04)
Log GDP		-0.90*	-0.43		-0.55		-0.65**	-0.26*		-0.27**
		(0.42)	(0.39)		(0.41)		(0.08)	(0.11)		(0.09)
Inflation				0.14	0.12				0.32**	0.35**
				(0.23)	(0.24)				(0.06)	(0.08)
Constant	0.61	14.08*	6.88	0.50	8.67	-0.12	9.54**	3.54+	-1.99**	1.76
	(1.32)	(6.92)	(6.50)	(2.40)	(7.11)	(0.48)	(1.35)	(1.93)	(0.60)	(1.36)
Obs	3,047	3,047	3,047	3,047	3,047	3,048	3,048	3,048	3,048	3,048
R-squared	0.16	0.14	0.26	0.29	0.39	0.40	0.21	0.46	0.59	0.64
Number of Months	304	304	304	304	304	304	304	304	304	304

Newey-West Standard Errors in Parentheses
** p<0.01, * p<0.05, + p<0.10

This table shows cross-sectional regressions of FX returns and forward discounts on the Import ratio as well as log of GDP and lagged 3-year inflation. Regressions are monthly using the previous calendar year's values of the independent variables. Fama-Macbeth standard errors are calculated using the Newey-West method with 36 lags. Data are monthly from 1988 to 2012.

Figure 7: Import Ratios and Exposure to Global Output Growth



This figure plots each country's slope coefficient from the regression

$$\Delta Productivity_{i,t} = \beta_i(\Delta GlobalOutput_t) + \epsilon_t$$

against the country's Import Ratio. Here $Productivity_{i,t}$ is real labor productivity for country i taken from the OECD, and $GlobalOutput_t$ is real output growth for the full OECD. The Import Ratio is calculated as in Figure 6. The trend line is from a regression of country β on country Import Ratio. The regression equation is also reported with OLS standard errors in parentheses.

size.

3.5 Real Exchange Rates and Relative Productivity

Another key implication of our model mechanism is the tight link between real exchange rates and productivity differentials in the final-good sectors across countries. In order to test this prediction we construct measures of real exchange rates and relative productivities for the key "commodity" and "producer" countries vis-a-vis their main trading partners (based on the imports and exports data). We consider the four commodity countries against their primary trading partners: Australia vs. Japan; Canada vs. Germany and Japan; New Zealand vs. Japan; and Norway vs. Germany, Japan, and Sweden.

It is difficult to construct a proxy for complex good manufacturing productivity at high frequencies, so as a proxy we again use quarterly data on aggregate labor productivity from the OECD. [13] The real exchange rate for each country is first calculated with respect to the U.S. (or equivalently any base currency) for each country i as $CPI^i \times Q^i/CPI^{US}$, where CPI data and currency values for each country are again from the OECD, where Q^i is the nominal exchange rate of country i in the units of US dollars. Countries' productivity and exchange rate series are aggregated in baskets by taking logs of the (equal weighted) geometric averages across countries. Relative productivities are then the differences of the two baskets' ("producer" and "commodity") average productivities. Figure 8 depicts the relative productivity differentials and real exchange rates for the four commodity countries and their producer country trading partners. In all of the cases the relative productivity measure appears to comove quite strongly with the real exchange rate.

Table 3.5 presents the results of regressions of the exchange rates between commodity and finished good producer-countries. Panel A presents evidence from regression of changes in average relative productivity over one or two quarters on the change in the corresponding basket real exchange rate over the same quarter, or the first quarter in the case of the two quarter specification. The latter approach is meant to capture time-aggregation of the underlying productivity series. The regression coefficients are always positive, and statistically significant in all cases with the exception of Norway. The R^2's are also quite sizeable, ranging between 5% and 20%, which suggests that relative productivity differentials comove with real exchange rates in a way consistent with our model's predictions. Panel B reports results for differences of real exchange rates and productivity ratios. While the raw regression coefficients are only robustly positive in the case of Norway vis-a-vis the group of its main trading partners, when a time trend is included, the slope coefficients are positive and highly statistically significant for the other countries, indicating strong comovement between real exchange rates and productivity differentials.

[13] In Section **??** of the appendix we also report similar analysis for levels of manufacting output using the adjusted "Production in total manufacturing" quantity index from the OECD. The results are qualitatively unchanged.

Table 3: Real Exchange Rates and Relative Productivity: G10 Countries

Panel A: Innovations

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$
$\Delta RER_{t,t+1}$	0.044**	0.085**	0.051**	0.101**	0.037	0.078	0.075**	0.117**
	(0.015)	(0.032)	(0.013)	(0.027)	(0.042)	(0.066)	(0.019)	(0.037)
Constant	-0.000	-0.001	-0.001	-0.001	0.001	0.002	-0.000	-0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	104	103	91	90	75	74	104	103
R^2	0.052	0.107	0.114	0.203	0.018	0.049	0.090	0.126

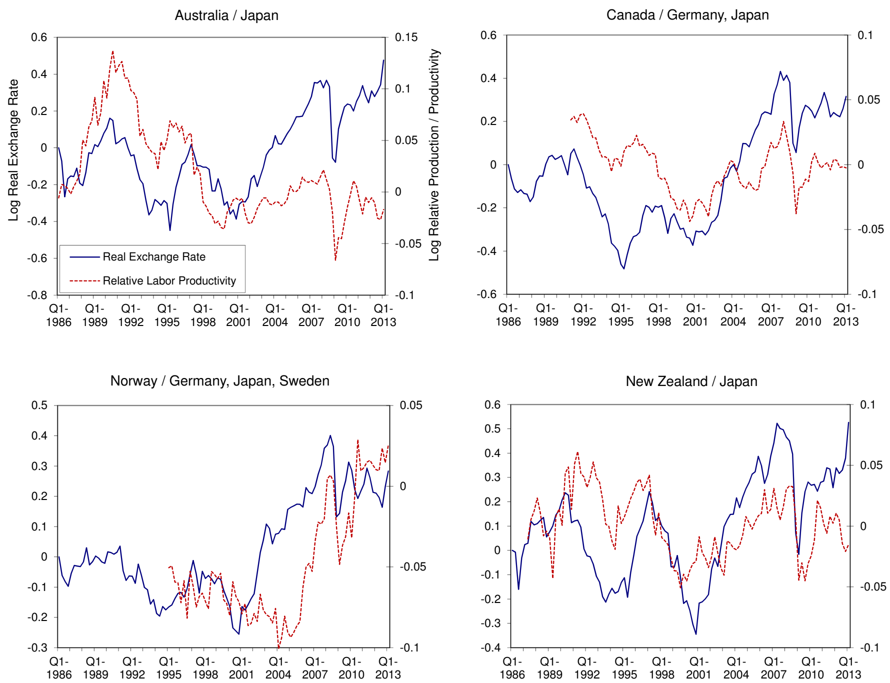
Panel B: Levels

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	RP_t	RP_T	RP_t	RP_T	RP_t	RP_T	RP_t	RP_T
RER_t	-0.024	0.115**	0.018	0.084**	0.139**	0.013	0.030	0.074**
	(0.047)	(0.022)	(0.018)	(0.015)	(0.043)	(0.065)	(0.024)	(0.022)
Trend		-0.002**		-0.001**		0.001*		-0.001**
		(0.000)		(0.000)		(0.001)		(0.000)
Constant	0.120	-0.355**	-0.039	-0.120**	-0.086**	-0.139**	-0.118	-0.260**
	(0.194)	(0.086)	(0.037)	(0.025)	(0.015)	(0.028)	(0.097)	(0.083)
Obs.	105	105	92	92	76	76	105	105
R^2	0.015	0.795	0.056	0.609	0.424	0.552	0.061	0.345

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.10

This table shows regressions of relative productivity (RP_t) against real exchange rates (RER_t). Each commodity country's exchange rate and relative productivity (the log difference of producer country and commodity country productivities) is calculated with respect to an equal weighted basket of its primary trading partners among the producer countries. Germany's exchange rate is calculated using the Euro post 1999. All exchange rates are converted to real using the relative value of the country CPI. Data are Quarterly. Panel A shows regressions of changes in relative productivity against changes in the real exchange rate. Each country includes two specifications, the first is of contemporaneous quarterly changes in relative productivity against contemporaneous changes in the real exchange rates, and the second is the sum of the contemporaneous quarter and the next quarter's change in relative productivity against this quarters change in real exchange rates to account for time-aggregation. Panel B shows regressions of levels of relative productivity against the level of the real exchange rate, both with and without and a time-trend. Relative productivity is calculated as the log-difference of real labor productivity from the OECD. Data are Quarterly. Newey-West standard errors with 4 lags are shown in parentheses.

Figure 8: Real Exchange Rates and Relative Productivity



3.6 Relative Productivity and Real Interest Rate differentials

The model also predicts that the movement in the real interest rate differentials is also driven by relative productivity, since it is the only state variable in our model. Indeed, Figure 9 demonstrates that a measure of real interest rate differentials for the pairs of countries described above, here constructed using a four-quarter moving average of inflation centered at the current observation as in Edison and Pauls (1993), comoves very closely with the corresponding relative productivity variable. Table 3.6 presents corresponding regression results. For all of the countries excluding Norway, the relationship between relative productivity and real interest rate differentials is strong and significant either in innovations or in levels.

3.7 Currency portfolios sorted on Import/Export data

In order to examine the patterns of average excess returns predicted by the model, we sort all of the countries in our sample into 5 portfolios (4 for the subsample of G10 countries) using the lagged import ratio. Specifically, in the beginning of January for each year t we

Table 4: Real Interest Rate Differentials and Relative Productivity: G10 Countries

Panel A: Innovations

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$	$\Delta RP_{t,t+1}$	$\Delta RP_{t,t+2}$
$\Delta RIR_{t,t+1}$	0.331	0.711*	0.061	0.658*	-0.317	-0.088	0.299	0.934**
	(0.242)	(0.349)	(0.222)	(0.293)	(0.247)	(0.289)	(0.366)	(0.256)
Constant	-0.000	-0.001	-0.000	-0.001	0.001	0.002	-0.000	-0.000
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	101	101	88	88	72	72	101	101
R^2	0.016	0.043	0.001	0.065	0.015	0.001	0.014	0.080

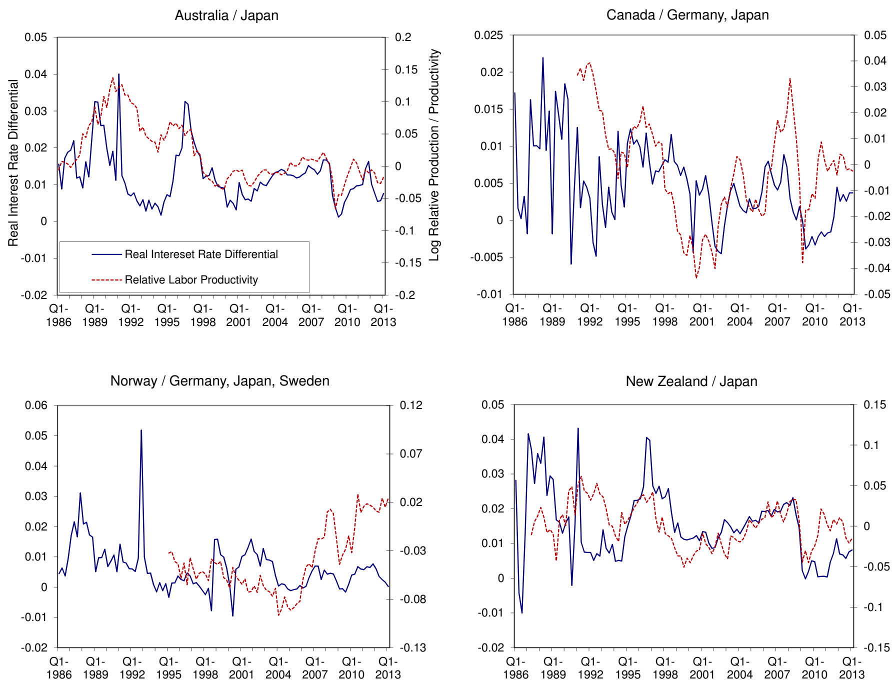
Panel B: Levels

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	RP_t	RP_t	RP_t	RP_t	RP_t	RP_t	RP_t	RP_t
RIR_t	2.680**	1.380**	1.607**	1.826**	-0.371	-0.283	0.805*	0.567
	(0.804)	(0.487)	(0.201)	(0.243)	(1.026)	(0.862)	(0.382)	(0.473)
Trend		-0.001**		0.000		0.001**		-0.000
		(0.000)		(0.000)		(0.000)		(0.000)
Constant	-0.012	0.069**	0.151**	0.324**	0.066	0.325*	0.075*	0.255**
	(0.040)	(0.040)	(0.038)	(0.078)	(0.080)	(0.146)	(0.036)	(0.095)
Obs.	101	101	89	89	73	73	101	101
R^2	0.181	0.626	0.486	0.503	0.003	0.500	0.076	0.124

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.10

This table shows regressions of relative productivity (RP_t) on real interest rate differentials (RIR_t) . Each commodity country's relative interest rate and relative productivity is calculated with respect to an equal weighted basket of its primary trading partners among the producer countries as in Table 3.5. Germany's interest rate is calculated using the Euro post 1999. All interest rates are converted to real by adjusting for predicted inflation calculated as a four quarter moving average of CPI growth centered at the observation. Data are quarterly. Newey-West standard errors with 4 lags are shown in parentheses.

Figure 9: Real Interest Rates and Relative Productivity



sort currencies based on the export ratio that is based on the trade data for the year $t-2$. This is because countries report their trade statistics to COMTRADE slowly, sometimes with complete reports available only by the end of the following year.

The construction of these portfolios represents an implementable trading strategy, relying only on trade data from available at the time of portfolio formation. Average forward discounts and average returns are computed from 1988-2012.

We work with one-month forward and spot exchange rates in units of foreign currency per U.S. dollar, denoted by F_t and S_t, respectively. Using the individual currency one-month forward discounts $f_t - s_t$ (lower case letters representing logarithms) and log excess returns approximated as

$$rx_{t+1} = f_t - s_{t+1},$$

we compute the log currency excess return rx^j_{t+1} for each portfolio $j = 1, 2 \ldots, 6$ by averaging over N_j currencies in the portfolio:

$$rx^j_{t+1} = \frac{1}{N_j} \sum_{i \in N_j} rx^i_{t+1}. \tag{21}$$

Similarly, currency portfolio excess returns (in levels) RX^j are computed by averaging individual currency excess returns in levels, $RX^i = (F^i_t - S^i_{t+1})/S^i_t$ analogously to (21). We do not take into account bid/ask spreads in the construction of these portfolios at the monthly frequency. Since our portfolios require very little rebalancing, transaction costs are likely to be small (returns based on long-horizon, e.g. one-year, forward contracts are typically similar to those obtained by rolling over shorter-horizon contracts; we report the results using one-year forward contracts with bid-ask spreads in the Data Appendix.).[14]

The results are reported in Panel I of Table 5. The results using both sorts are very similar: portfolios representing large complex good exports and basic good imports relative to their output have low average forward discounts, suggesting that they capture countries whose interest rates are typically low relative to the U.S. Conversely, portfolios with high values of commodity exports and low values of final good exports exhibit high average forward discount, indicating high average interest rates. The pattern is virtually monotonic across portfolios, especially for developed countries subsample, with differences between the highest and the lowest portfolios' average forward discounts of around 4% per annum for the basic good sort over 5% per annum for the complex good sort.

Importantly, portfolio average excess returns follow the pattern of the average forward discounts, being negative for the low portfolios and positive for the high portfolios, with the spreads in average returns between extreme portfolios close to 4% per year for both the basic good sort and the complex good sort. Thus, the differences in the average forward discounts translate almost fully into average excess returns, contrary to the UIP hypothesis. Since the sorting variables are very persistent, these differences are likely to capture unconditional rather than conditional risk premia. To facilitate comparison with traditional carry-trade strategies, we sort countries based on forward discounts at the same frequency as the import-

[14]The portfolio is rebalanced to handle the introduction of the Euro. Prior to 1999 breakpoints are calculated including the component countries of the Euro as separate entities. Post 1999 the breakpoints are recalculated counting the Eurozone as a single country.

sorted portfolios. That is, each January we sort currencies based on their forward discount vis-a-vis the U.S. dollar at the end of December. This puts the import sort on equal footing with the carry-trade sort in the sense that the information used to update the portfolios arrives at the same frequency (in both cases the portfolios are rebalanced monthly). The annual portfolio formation period departs from the traditional method of sorting currencies based on the current interest rate in each month as in Lustig, Roussanov, and Verdelhan (2011). The resulting annual sort displays somewhat less variation in average forward discounts across portfolios and a narrower spread in average excess returns that the month sort as in Lustig, Roussanov, and Verdelhan (2011). Average forward discounts and excess returns for these portfolios are shown in Panel II of Table 5. Both the spread in the average forward discounts and that in average excess returns are essentially of the same magnitude as those in the obtained using the import ratio sort in Panel I.

3.8 Explaining the carry trade with IMX factor

Lustig, Roussanov, and Verdelhan (2011) show that carry-sorted exhibit strong factor structure that implies heterogeneity in countries' SDFs exposures to a global source of risk, which is corroborated by the fact that average returns on carry portfolios line up with loadings on a common factor. If our model is a good description of such heterogeneity in risk exposures then import-sorted portfolios should exhibit similar properties. As a candidate for the risk factor capturing global SDF shocks we consider returns on a portfolio which is long the portfolio with the highest import ratio and short the lowest import ratio. We refer to this strategy as IMX (*Importers Minus eXporters* of finished goods).

Table 6 present results of standard asset pricing tests using both the full sample of countries and the smaller G10 sample. Panel lists displays cross-sectional estimates of the IMX market price of risk λ_{IMX} and the corresponding SDF loading b_{IMX} using both the SDF-GMM methodology and the Fama-MacBeth approach, together with the cross-sectional pricing error tests. Panel II lists estimated time-series estimates of factor loadings β^i_{IMX} for each portfolio as well as the pricing error α^i_0, as well as the joint test statistics for the alphas. The tests show that the prices of risk and factor loadings, while imprecisely estimated (given the relatively short length of the sample) are nevertheless statistically significant using most

Table 5: Currency Portfolios Sorted on Combined Imports/Exports Measure

Portfolio	1	2	3	4	5	1	2	3	4
	Panel I: Portfolios Sorted on Import Ratios								
	All Countries					G10 Countries			
	Forward Discount: $f^j - s^j$					$f^j - s^j$			
Mean	−0.45	−0.41	0.70	0.67	2.58	−1.93	0.42	1.24	2.52
Std	0.73	0.66	0.78	0.60	0.52	0.70	0.71	0.51	0.54
	Log Excess Return: rx^j					rx^j			
Mean	−0.95	0.36	0.84	0.96	3.76	−0.87	0.36	1.38	3.49
Std	8.57	11.11	8.42	7.73	9.67	9.56	10.80	7.08	9.69
SR	−0.11	0.03	0.10	0.12	0.39	−0.09	0.03	0.20	0.36
	Excess Return: Rx^j					Rx^j			
Mean	−0.36	1.03	1.30	1.40	4.41	−0.24	1.00	1.77	4.14
Std	8.55	11.09	8.36	7.69	9.62	9.58	10.75	7.03	9.64
SR	−0.04	0.09	0.16	0.18	0.46	−0.02	0.09	0.25	0.43
	Panel II: Portfolios Sorted on Forward Discounts								
	All Countries					G10 Countries			
	Forward Discount: $f^j - s^j$					$f^j - s^j$			
Mean	−2.30	−0.67	0.66	1.61	3.78	−2.18	−0.02	1.28	3.51
Std	0.64	0.57	0.58	0.69	0.81	0.63	0.50	0.61	0.78
	Log Excess Return: rx^j					rx^j			
Mean	−0.24	1.33	3.32	2.81	4.07	−0.28	2.80	2.58	4.24
Std	9.45	9.62	9.59	8.71	10.27	10.04	8.51	8.89	10.29
SR	−0.03	0.14	0.35	0.32	0.40	−0.03	0.33	0.29	0.41
	Excess Return: Rx^j					Rx^j			
Mean	0.33	1.91	3.86	3.32	4.79	0.38	3.27	3.08	4.96
Std	9.47	9.64	9.60	8.65	10.20	10.09	8.49	8.84	10.23
SR	0.04	0.20	0.40	0.38	0.47	0.04	0.39	0.35	0.48

This table reports average forward discounts and average (log and level) excess returns on currency portfolios sorted on the Import Ratio (panel I) and on log forward discounts (panel II). The Import Ratio is constructed by adding the level of net exports in basic goods to the level of net imports in finished goods, and then dividing by the level of manufacturing output of the country, as prescribed by the model. The rankings are updated at the end of each using the prior year's trade data or current forward discounts. Trade data are annual, from UN Comtrade (available via NBER extracts). Forward and spot exchange rate data are monthly, from Barclays and Reuters (available via Datastream). The returns do not take into account bid-ask spreads. The sample period is 2/1988 to 4/2013.

methods and are broadly consistent in magnitudes with the mean of the IMX factor (4.53% in the full sample and 4.11% in the G10 sample. More importantly, the pricing errors are not statistically significant either individual or jointly using any method. Factor betas are essentially monotonically increasing in the import ratio. This evidence is consistent with the notion that the spread in average returns on import-sorted portfolios is driven by differences in exposures to a common source of risk captured by the IMX strategy.

Table 6 presents similar evidence but now using the carry-sorted portfolios as the test assets for the IMX factor. At the level of individual portfolios the factor betas exhibit the same monotonic pattern, increasing with interest rate differential. Individual pricing errors are not statistically significantly different from zero, and are jointly at only at 10% level (p-value of 9.32%) in the full sample. The implied prices of risk are somewhat larger (but not statistically significantly so). This is potentially due to the somewhat smaller spread in betas, indicating potential measurement error problems stemming either from the mismeasurement of real interest rate differentials using forward discounts or, more likely, of the import ratios constructed using trade data. This evidence broadly indicates, however, that the import-sorted and carry-sorted portfolios share a common source of risk that drives heterogeneity in average returns, consistent with the model's predictions.

3.9 Case study: the global financial crisis

As a further illustration of the model mechanisms in the data, we examine the behavior of model variables during the global financial crisis, which coincided with a dramatic decline in output, especially among final-good producer countries, such as Japan, and a collapse in international trade volume (e.g. see Eaton, Kortum, Neiman, and Romalis (2011)). As Figure 10 shows, the data lines up nicely with the model predictions over this period. Panel A shows that the commodity currencies tended to depreciate relative to final-good producer currencies during the crisis. Panel B illustrates that this is reflected in a large negative return on the IMX strategy, and that this return is accompanied by large negative changes in the CRB Commodity Spot Index and the Baltic Dry Index. Perhaps most importantly, even though commodity prices were dropping during this period, Panel C shows the productivity of the commodity countries did not fall as severely as that of the producer countries. The

Table 6: Asset Pricing Tests: Portfolios Sorted by Import Ratio

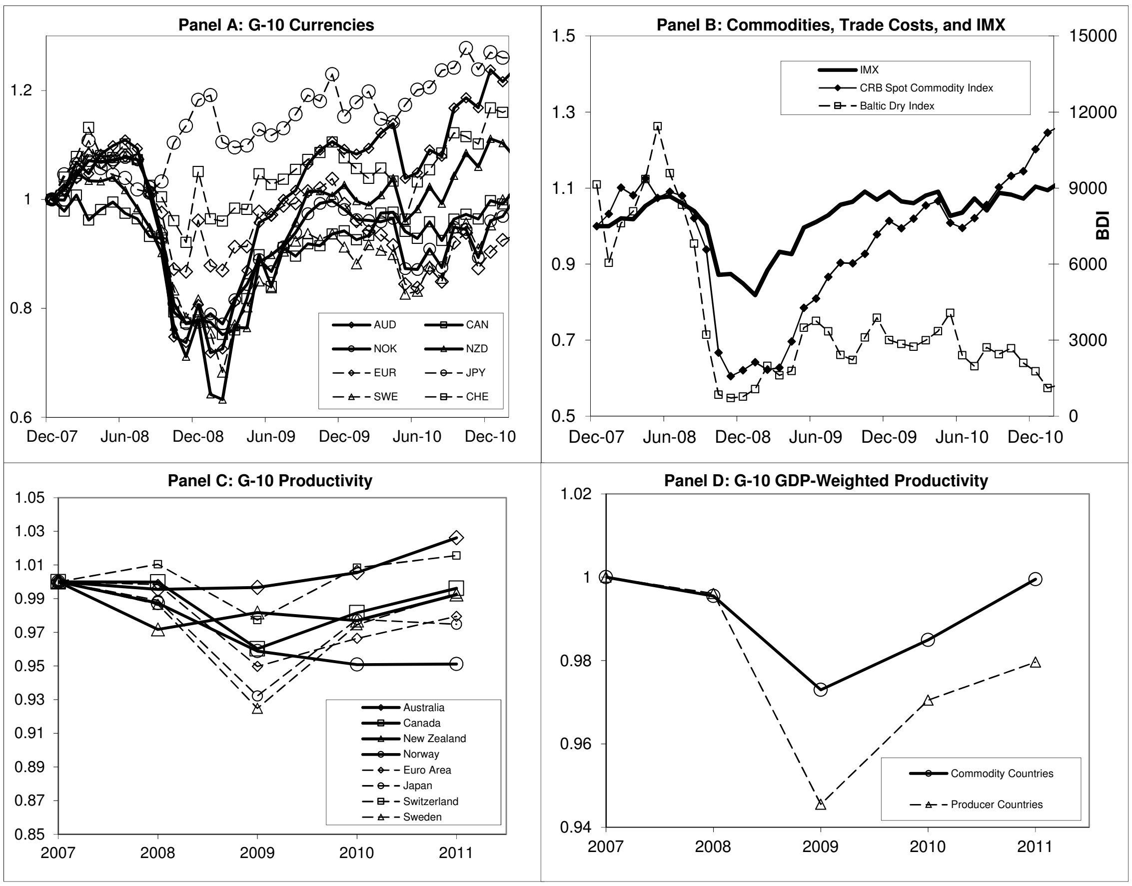
Panel I: Risk Prices										
	All Countries					G10 Countries				
	λ_{IMX}	b_{IMX}	R^2	$RMSE$	χ^2	λ_{IMX}	b_{IMX}	R^2	$RMSE$	χ^2
GMM_1	5.71	0.65	37.71	1.16		4.70	0.43	−12.59	1.58	
	[3.23]	[0.37]			68.19	[2.89]	[0.27]			55.03
GMM_2	4.50	0.51	29.67	1.23		4.31	0.40	−13.52	1.59	
	[2.00]	[0.23]			74.92	[2.35]	[0.22]			55.59
FMB	5.71	0.65	86.92	1.16		4.70	0.43	83.98	1.58	
	[2.37]	[0.27]			73.62	[2.05]	[0.19]			48.21
	[2.39]	[0.27]			74.93	[2.05]	[0.19]			49.12
$Mean$	4.53					4.11				

Panel II: Factor Betas and Pricing Errors										
	All Countries					G10 Countries				
$Portfolio$	α_0^j	β_{IMX}^j	R^2	$\chi^2(\alpha)$	$p-val$	α_0^j	β_{IMX}^j	R^2	$\chi^2(\alpha)$	$p-val$
1	1.52	−0.36	13.18			2.03	−0.49	23.46		
	[1.70]	[0.08]				[1.80]	[0.08]			
2	0.93	0.09	0.54			1.03	0.06	0.26		
	[2.34]	[0.11]				[2.45]	[0.12]			
3	1.31	0.05	0.23			0.95	0.21	8.34		
	[1.84]	[0.09]				[1.51]	[0.08]			
4	0.63	0.20	5.06			2.03	0.51	25.60		
	[1.71]	[0.09]				[1.80]	[0.08]			
5	1.52	0.64	32.39							
	[1.70]	[0.08]								
				1.80	87.60				2.17	70.53

Notes: The panel on the left reports results for all countries in our sample. The panel on the right reports results for the G10 group of developed countries with most widely-traded currencies. Panel I reports results from GMM and Fama-McBeth asset pricing tests. Market prices of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$ and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes stochastic discount factor loadings on the IMX strategy return. All excess returns are multiplied by 12 (annualized). Shanken (1992)-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas and alphas (pricing errors) for each of the portfolios. R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The χ^2 test statistic $\alpha' V_\alpha^{-1} \alpha$ tests the null that all intercepts are jointly zero. This statistic is constructed from the Newey-West variance-covariance matrix (1 lag) for the system of equations (see Cochrane (2005), p. 234). Data are monthly, from Barclays and Reuters in Datastream. The sample period is 2/1988–4/2013. The alphas are annualized and in percentage points.

outliers are two of the smaller countries within each group, New Zealand and Switzerland. Panel D shows that a GDP-weighted basket of commodity countries' productivity greatly outperforms that of final-goods producers during the crisis.

Figure 10: Currencies, Commodities, Trade Costs, and Productivity During the Crisis



Currency and economic variables during the global financial crisis. Panel A shows monthly cumulative currency returns on the four G10 "commodity countries" (Australia, Canada, New Zealand, and Norway) and the four G10 "producer countries" (Europe, Japan, Switzerland, and Sweden). Panel B shows the monthly performance of the IMX strategy as well as monthly changes in the Commodity Research Bureau All Commodity spot index and the Baltic Dry Index (BDI). Panel C shows the productivity growth of the eight countries, and Panel D shows the productivity growth of GDP-weighted baskets of the two country groups. All exchange rate, commodity price, and consumption variables normalized to one in December 2007. Data from Datastream and the OECD.

Table 7: Asset Pricing Tests: Portfolios Sorted by Forward Discounts

Panel I: Risk Prices										
	All Countries					G10 Countries				
	λ_{IMX}	b_{IMX}	R^2	$RMSE$	χ^2	λ_{IMX}	b_{IMX}	R^2	$RMSE$	χ^2
GMM_1	10.58	1.20	78.20	1.21		7.84	0.72	56.64	1.67	
	[7.17]	[0.81]			61.94	[4.06]	[0.38]			21.54
GMM_2	12.12	1.38	75.87	1.27		6.20	0.57	52.09	1.75	
	[4.43]	[0.50]			64.07	[3.20]	[0.30]			24.03
FMB	10.58	1.20	78.21	1.21		7.84	0.72	75.48	1.67	
	[4.21]	[0.48]			13.42	[2.56]	[0.24]			11.30
	[4.43]	[0.50]			18.19	[2.60]	[0.24]			12.99
$Mean$	4.53					4.11				

Panel II: Factor Betas and Pricing Errors										
	All Countries					G10 Countries				
$Portfolio$	α_0^j	β_{IMX}^j	R^2	$\chi^2(\alpha)$	$p-val$	α_0^j	β_{IMX}^j	R^2	$\chi^2(\alpha)$	$p-val$
1	−0.78	−0.22	4.27			0.54	−0.43	19.16		
	[1.84]	[0.08]				[1.83]	0.09			
2	−1.75	0.11	1.11			−0.63	0.11	1.36		
	[1.95]	[0.10]				[1.86]	0.08			
3	1.58	0.15	2.06			2.69	0.22	5.35		
	[1.99]	[0.09]				[1.93]	0.09			
4	2.31	0.23	5.15			3.04	0.44	16.66		
	[1.88]	[0.09]				[2.07]	0.09			
5	2.81	0.44	13.46							
	[2.16]	[0.11]								
				9.43	9.32				7.02	13.48

Notes: The panel on the left reports results for all countries in our sample. The panel on the right reports results for the G10 group of developed countries with most widely-traded currencies. Panel I reports results from GMM and Fama-McBeth asset pricing tests. Market prices of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$ and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes stochastic discount factor loadings on the IMX strategy return. All excess returns are multiplied by 12 (annualized). Shanken (1992)-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas and alphas (pricing errors) for each of the portfolios. R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The χ^2 test statistic $\alpha' V_\alpha^{-1} \alpha$ tests the null that all intercepts are jointly zero. This statistic is constructed from the Newey-West variance-covariance matrix with 1 lag. Data are monthly, from Barclays and Reuters in Datastream. The sample period is 2/1988–4/2013. The alphas are annualized and in percentage points.

3.10 Conditional Asset Pricing Implications

The evidence on cross-sectional behavior of expected currency excess returns based on the asset pricing tests reported in Section 3.8 above is consistent with the unconditional implications of our model (commodity currency is riskier on average) as well as its conditional implications. The latter is because variation in a country's import ratio over time determines which portfolio it is sorted into, so that unconditional betas at the portfolio level capture conditional covariances of individual currencies with the IMX factor (Cochrane (2011) stresses this interpretation of the cross-sectional evidence in Lustig, Roussanov, and Verdelhan (2011)). However, these tests do not fully exploit our model's predictions for the conditional expected returns on the currency carry trade. Specifically, implication (3) in Section 2.7 suggests that the conditional expected returns on the IMX strategy should vary over time, being higher when relative productivity of commodity countries relative to producer countries is greater, and lower otherwise.

Testing this prediction is complicated by the fact that both our relative productivity measure and the import ratio that proxies for relative productivity according to the model are time-aggregated at annual frequency. As a consequence, they make for very noisy instruments for summarizing conditioning information available at a particular point in time, especially for capturing conditional expected returns that vary over relatively short horizons. Fortunately, we can exploit our model's predictions for the behavior of trade/shipping costs to use variables that are observed at a particular point in time, as suggested by equation (12). In particular, we can use the Baltic Dry Index (BDI) of the spot freight rates for dry bulk goods available from the Baltic Exchange as a proxy for trade costs. While the model notion of trade costs is wider than just the costs of shipping, to the extent that shipping costs increase with the amount of goods exported, as the supply of ships is inelastic in the short run, they serve as a good proxy for the relative productivity that is not observed at high enough frequency. Given the highly persistent nature of the BDI variable, we use its monthly growth rate, $\Delta BDI_{t+1} = \frac{BDI_{t+1}}{BDI_t}$ as the conditioning variable in order to reduce the possibility of small-sample bias associated with persistent predictors.

In order to test the conditional implications of our model we expand the set of test assets by augmenting it with returns on "managed portfolios"; i.e. test portfolio returns "scaled" by the conditioning variable, $\tilde{Rx}_{t+1} = Rx_{t+1} \otimes z_t$, where z_t is the conditioning variable (in the GMM context this amounts to enlarging the set of moment conditions by instrumenting using z_t, e.g. as introduced in Hansen and Singleton (1982). We also allow the price of risk associated with IMX estimated in the cross-sectional regression to depend on the conditioning variable, so that $\lambda_t^{IMX} = \lambda_0 + \lambda_1 \Delta BDI_t$, which is equivalent to expanding the the set of priced factors in the SDF to $f_{t+1} = [IMX_{t+1}, \Delta BDI_t \times IMX_{t+1}]$. This approach to testing conditional asset pricing models using scaled factors in conjunction managed portfolios is advocated by Cochrane (1996)). Nagel and Singleton (2010) develop a procedure that maximizes the power of the conditional tests, while Roussanov (2014) incorporates flexible nonparametric estimation of the conditional prices of risk. Here we pursue the standard approach for simplicity.

We present the results of our conditional tests in Table 8. We consider two sets of test assets separately: those based on the Import ratio sort and on the forward discount (Carry) sort. The first five test assets (numbered 1-5) in each set are the original sorted portfolios, while the remaining portfolios (6-10) are the original ones scaled with ΔBDI_t. Panel I reports the price of risk and SDF factor loadings together with the cross-sectional tests using either the GMM or the Fama-Macbeth methodology (p-values for the appropriate χ^2 test statistic are reported in each case). Panel II reports the time-series regression results for each portfolio (alphas, betas, and R^2) as well as the cross-sectional GRS tests. For the import-sorted portfolios both λ_0 and λ_1 are positive and statistically significant, indicating that not only is IMX priced in the cross-section of currency returns, but its price of risk varies over time with shipping costs, as predicted by the model. Their magnitudes are also consistent with the average returns on the corresponding factor-mimicking portfolios. The SDF factor loadings b are generally less precisely estimated and therefore not significant except using the (efficient) second-stage GMM, where b_1 is significant. The results are similar for the Carry-sorted portfolio; the magnitudes of risk prices are somewhat larger in this case but not significantly different from the factor sample means. Crucially, in both cases the cross-sectional pricing error tests fail to reject the model. This is consistent with the evidence from portfolio-level tests where none of the alphas are statistically significantly different from zero.

4 Conclusion

We present new evidence on the currency carry trade: countries that specialize in exporting basic goods such as raw commodities tend to exhibit high interest rates where as countries primarily exporting finished goods have lower interest rates on average. These interest rate differences translate almost entirely into average returns on currency carry trade strategies. We propose a novel mechanism that helps rationalize these findings: comparative advantage in production of different types of goods combined with convex trade costs and time-varying capacity of the shipping industry. Nonlinearity of the trade costs, as well as the ability of the commodity country to insure itself through domestic production, imply that the SDF of the country that is more efficient at producing the consumption good is more sensitive to productivity shocks, making its currency a "safe haven" and commodity country currency risky. Our model's empirical predictions are strongly supported in the data.

Table 8: Asset Pricing Tests with Conditioning Information

Panel I: Risk Prices										
	Import Sort					Carry Sort				
	λ_{IMX}	$\lambda_{IMX\times BDI}$	b_{IMX}	$b_{IMX\times BDI}$	χ^2	λ_{IMX}	$\lambda_{IMX\times BDI}$	b_{IMX}	$b_{IMX\times BDI}$	χ^2
GMM_1	4.94	7.66	−0.55	1.06		9.19	10.96	0.44	0.51	
	[1.80]	[3.20]	[1.41]	[1.29]	20.99	[4.21]	[5.65]	[1.10]	[1.08]	74.66
GMM_2	5.45	7.79	−0.31	0.89		11.36	13.03	0.78	0.74	
	[1.69]	[1.96]	[0.38]	[0.32]	23.35	[2.96]	[2.84]	[0.55]	[0.29]	80.32
FMB	4.94	7.66	−0.55	1.06		9.19	10.96	0.44	0.51	
	[1.79]	[2.90]	[1.25]	[1.14]	17.27	[3.11]	[4.48]	[1.00]	[0.99]	60.55
	[1.80]	[2.94]	[1.28]	[1.17]	20.44	[3.22]	[4.66]	[1.04]	[1.03]	67.24
$Mean$	4.60	6.67				4.60	6.67			

Panel II: Factor Betas and Pricing Errors										
	All Countries					G10 Countries				
$Portfolio$	α_0^j	β_{IMX}^j	$\beta_{IMX\times BDI}$	R^2	χ^2	α_0^j	β_{IMX}^j	$\beta_{IMX\times BDI}$	R^2	χ^2
1	1.22	−0.53	0.16	13.90		−0.86	−0.57	0.34	7.13	
	[1.66]	[0.23]	[0.17]			[1.85]	[0.19]	[0.17]		
2	0.20	−0.28	0.36	2.58		0.38	−0.12	0.12	0.34	
	[2.35]	[0.30]	[0.23]			[1.86]	[0.29]	[0.21]		
3	1.13	−0.05	0.09	0.48		1.76	−0.00	0.21	4.74	
	[1.84]	[0.21]	[0.16]			[1.96]	[0.28]	[0.19]		
4	0.62	0.20	−0.00	5.05		1.21	0.30	−0.05	6.60	
	[1.61]	[0.24]	[0.17]			[1.81]	[0.24]	[0.18]		
5	1.22	0.47	0.16	32.97		1.20	0.25	0.16	13.57	
	[1.66]	[0.23]	[0.17]			[2.14]	[0.28]	[0.21]		
6	1.37	−0.41	0.07	10.88		−1.57	−0.90	0.73	11.61	
	[1.71]	[0.21]	[0.18]			[1.99]	[0.40]	[0.38]		
7	−0.41	−0.95	1.09	15.43		0.58	−0.12	0.15	0.63	
	[2.48]	[0.46]	[0.41]			[1.86]	[0.13]	[0.11]		
8	0.55	−0.40	0.45	5.44		1.56	−0.49	0.75	13.66	
	[1.94]	[0.22]	[0.19]			[2.06]	[0.23]	[0.19]		
9	0.74	−0.21	0.40	8.71		1.09	−0.20	0.43	10.06	
	[1.69]	[0.18]	[0.15]			[1.83]	[0.17]	[0.14]		
10	1.37	−0.41	1.07	46.64		1.36	−0.59	1.03	28.04	
	[1.71]	[0.21]	[0.18]			[2.13]	[0.32]	[0.28]		
					30.49					48.97

Notes: Test assets include the original portfolios (1-5) sorted on either the Import ratio or the Forward discount (Carry sort) as well as the same portfolio returns scaled with the conditioning variable BDI (6-10). All excess returns are multiplied by 12 (annualized). Panel I reports results from GMM and Fama-McBeth asset pricing tests. Market prices of risk λ and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes stochastic discount factor loadings on the IMX strategy return. Shanken (1992)-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas and alphas (pricing errors) for each of the portfolios. R^2s and p-values are reported in percentage points.

References

Adler, Michael, and Bruce Lehmann, 1983, Deviations from purchasing power parity in the long run, *Journal of Finance* 38, 1471–1487.

Alvarez, Fernando, Andrew Atkeson, and Patrick J. Kehoe, 2002, Money, interest rates and exchange rates with endogenously segmented markets, *Journal of Political Economy* 110(1), 73–112.

Andrews, Donald W.K., 1991, Heteroskedasticity and autocorrelation consistent covariance matrix estimation, *Econometrica* 59, 817–858.

Arkolakis, Costas, 2010, Market Penetration Costs and the New Consumers Margin in International Trade, *Journal of Political Economy* 118, 1151 – 1199.

Backus, David, Patrick Kehoe, and Finn Kydland, 1992, International real business cycles, *Journal of Political Economy* 100, 745–75.

Backus, David, and Gregor Smith, 1993, Consumption and real exchange rates in dynamic economies with non-traded goods, *Journal of International Economics* 35, 297–316.

Backus, David K, Patrick J Kehoe, and Finn E Kydland, 1994, Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?, *American Economic Review* 84, 84–103.

Bakshi, Gurdip, Peter Carr, and Liuren Wu, 2008, Stochastic risk premiums, stochastic skewness in currency options, and stochastic discount factors in international economies, *Journal of Financial Economics* 87, 132–156.

Bakshi, Gurdip, and George Panayotov, 2013, Predictability of currency carry trades and asset pricing implications, *Journal of Financial Economics* 110, 139 – 163.

Bansal, Ravi, and Magnus Dahlquist, 2000, The forward premium puzzle: Different tales from developed and emerging economies, *Journal of International Economics* 51, 115–144.

Bansal, Ravi, and Ivan Shaliastovich, 2012, A long-run risks explanation of predictability puzzles in bond and currency markets, *Review of Financial Studies*.

Campbell, John Y., Karine Serfaty De Medeiros, and Luis M. Viceira, 2010, Global currency hedging, *Journal of Finance* 65, 87–121.

Cochrane, John H., 1996, A cross-sectional test of an investment-based asset pricing model, *Journal of Political Economy* 104, 572–621.

——— , 2005, *Asset Pricing* (Princeton University Press: Princeton, NJ).

——— , 2011, Presidential address: Discount rates, *The Journal of Finance* 66, 1047–1108.

Colacito, R., and M. Croce, 2012, International asset pricing with recursive preferences, *Journal of Finance, forthcoming.*

Colacito, Riccardo, and Mariano M. Croce, 2010, Risk Sharing for the Long-Run: A General Equilibrium Approach to International Finance with Recursive Preferences and Long-Run Risks, *SSRN eLibrary.*

——— , 2011, Risks for the long run and the real exchange rate, *Journal of Political Economy* 119, 153–182.

Dumas, Bernard, 1992, Dynamic equilibrium and the real exchange rate in a spatially separated world, *Review of Financial Studies* 5, 153–80.

Eaton, Jonathan, Samuel Kortum, Brent Neiman, and John Romalis, 2011, Trade and the global recession, Working Paper 16666 National Bureau of Economic Research.

Edison, Hali J, and B Dianne Pauls, 1993, A re-assessment of the relationship between real exchange rates and real interest rates: 1974–1990, *Journal of Monetary Economics* 31, 165–187.

Fama, Eugene F., 1984, Forward and spot exchange rates, *Journal of Monetary Economics* 14, 319–338.

——— , and James MacBeth, 1973, Risk, return and equilibrium: Empirical tests, *Journal of Political Economy* 81, 607–636.

Ferraro, Domenico, Barbara Rossi, and Kenneth S. Rogoff, 2011, Can Oil Prices Forecast Exchange Rates?, *Duke University Working Paper.*

Fitzgerald, Doireann, 2012, Trade costs, asset market frictions, and risk sharing, *American Economic Review* 102, 2700–2733.

Froot, Kenneth A., and Maurice Obstfeld, 1991, Exchange-rate dynamics under stochastic regime shifts: A unified approach, *Journal of International Economics* 31, 203–229.

Greenwood, Robin, and Samuel G. Hanson, 2015, Waves in ship prices and investment, *Quarterly Journal of Economics* pp. 55–109.

Hansen, Lars P., 1982, Large sample properties of generalized method of moments estimators, *Econometrica* 50, 1029–1054.

———, and Kenneth J. Singleton, 1982, Generalized instrumental variables estimation of nonlinear rational expectations models, *Econometrica* 50, 1296–1286.

Harrison, J. Michael, 1985, *Brownian Motion and Stochastic Flow Systems* (John Wiley & Sons: New York).

Hassan, Tarek A., 2013, Country size, currency unions, and international asset returns, *The Journal of Finance* 68, 2269–2308.

Hassan, Tarek A, and Rui C Mano, 2014, Forward and spot exchange rates in a multi-currency world, Discussion paper National Bureau of Economic Research.

Hollifield, Burton, and Raman Uppal, 1997, An examination of uncovered interest rate parity in segmented international commodity markets, *Journal of Finance* 52, 2145–2170.

Hummels, David, 2007, Transportation costs and international trade in the second era of globalization, *Journal of Economic Perspectives* 21, 131–154.

Kalouptsidi, Myrto, 2014, Time to build and fluctuations in bulk shipping, *American Economic Review* 104, 564–608.

Koijen, Ralph S.J., Lasse Heje Pedersen, Tobias J. Moskowitz, and Evert B. Vrugt, 2012, Carry, Chicago Booth working paper.

Lettau, Martin, Matteo Maggiori, and Michael Weber, 2013, Conditional risk premia in currency markets and other asset classes, Working Paper 18844 National Bureau of Economic Research.

Lewis, Karen K., 1995, Puzzles in international financial markets, in G. Grossman, and K. Rogoff, ed.: *Handbook of International Economics, Vol.III* (Elsevier: Amsterdam).

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2011, Common risk factors in currency returns, *Review of Financial Studies* 24, 3731–3777.

——— , 2013, Countercyclical currency risk premia, *Journal of Financial Economics, forthcoming.*

Lustig, Hanno, and Adrien Verdelhan, 2007, The cross-section of foreign currency risk premia and consumption growth risk, *American Economic Review* 97, 89–117.

Lyons, Richard K., 2001, *The Microstructure Approach to Exchange Rates* (MIT Press).

Martin, Ian, 2011, The Forward Premium Puzzle in a Two-Country World, *NBER Working Paper no. 17564.*

Meese, Richard, and Kenneth Rogoff, 1983, Empirical exchange rate models of the seventies: Do they fit out-of-sample?, *Journal of International Economics* 14.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, 2012, Carry trades and global foreign exchange rate volatility, *Journal of Finance* 67 (2), 681–718.

Nagel, Stefan, and Kenneth Singleton, 2010, Estimation and evaluation of conditional asset pricing models, *Journal of Finance, forthcoming.*

Newey, Whitney K., and Kenneth D. West, 1987, A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix, *Econometrica* 55, 703–708.

Obstfeld, Maurice, and Kenneth Rogoff, 2001, The six major puzzles in international macroeconomics: is there a common cause?, in *NBER Macroeconomics Annual 2000, Volume 15* . pp. 339–412 (MIT press).

Pavlova, Anna, and Roberto Rigobon, 2007, Asset prices and exchange rates, *Review of Financial Studies* 20, 1139–1180.

Ramanarayanan, Ananth, and Simona E. Cociuba, 2011, International risk sharing with endogenously segmented asset markets, Discussion paper.

Ready, Robert, Nikolai Roussanov, and Colin Ward, 2013, Commodity Trade and the Carry Trade: a Tale of Two Countries, *NBER Working Paper no. 19371.*

Rogoff, Kenneth, 1996, The Purchasing Power Parity Puzzle, *Journal of Economic Literature* 34, 647–668.

Roussanov, Nikolai, 2014, Composition of wealth, conditioning information, and the cross-section of stock returns, *Journal of Financial Economics* 111, 352380.

Shanken, Jay, 1992, On the estimation of beta-pricing models, *The Review of Financial Studies* 5, 1–33.

Stathopoulos, Andreas, 2011, Asset prices and risk sharing in open economies, working paper.

——— , Andrea Vedolin, and Philippe Mueller, 2012, International correlation risk, working paper.

Stokey, Nancy, 2009, *The Economics of Inaction: Stochastic Control Models with Fixed Costs* (Princeton University Press: Princeton, NJ).

Svensson, Lars E.O., 1991, Target zones and interest rate variability, *Journal of International Economics* 31, 27–54.

Verdelhan, Adrien, 2010, A habit-based explanation of the exchange rate risk premium, *Journal of Finance* 65, 123–145.

Appendix

Additional Derivations and Proofs

Relative productivity

To focus on the countries' relative productivities, we project the imperfectly correlated Brownian motions dB_c and dB onto each other, leaving a residual that is a stochastic integral with respect to an independent Brownian motion, B_z: more specifically, we construct $dB_c = \rho dB_z + \sqrt{1-\rho^2}dB$. We then define z by the equation $z_p z \doteq z_{cp}$ and derive z_{cp} as a general process from here.

$$z_p z \doteq z_{cp} \tag{A-1}$$

$$dz_p z + z_p dz + dz dz_p = dz_{cp} \tag{A-2}$$

$$z z_p(\mu dt + \sigma dB) + (\mu_{zt} dt + \sigma_z dB_z + dL - dU) z_p = \mu(z_{cp})dt + \sigma(z_{cp})dB_c \tag{A-3}$$

$$= \mu(z_{cp})dt + \sigma(z_{cp}) \left(\rho dB_z + \sqrt{1-\rho^2}dB\right) \tag{A-4}$$

We then need to solve a system of three equations for $\mu(z_{cp})$, $\sigma(z_{cp})$ and ρ:

$$\begin{aligned} \mu(z_{cp})dt &= z\mu z_p dt + \mu_{zt} z_p dt + z_p dL - z_p dU \\ \sigma(z_{cp})\rho &= \sigma_z z_p \\ \sigma(z_{cp})\sqrt{1-\rho^2} &= z\sigma z_p \end{aligned}$$

Solving this system we get $\rho = \sqrt{\frac{\sigma_z^2}{\sigma_z^2 + z^2\sigma^2}}$, $\sigma(z_{cp}) = z_p\sqrt{\sigma_z^2 + z^2\sigma^2}$, and $\mu(z_{cp})dt = \mu_{zt} z_p dt + z\mu z_p dt - z_p dU + z_p dL$, where for clarity we include the regulator terms dL and dU in the general drift term of z_{cp}.

The projection implies an interesting result: the processes for z_{cp} and z_p are highly correlated when their technologies for producing the final good are similar—when z_{cp} is close to z_p. To see this, when z increases, then ρ decreases, and thus the correlation between dB_c and dB, $\sqrt{1-\rho^2}$, increases. All together, we get a stochastic process z that takes values on

$(\underline{z}, 1)$:

$$dz = \mu_{zt}dt + \sigma_z dB_z - dU + dL.$$

Before formally defining $U(t)$ and $L(t)$, first define $z(t)$ as the sum of an arithmetic Brownian motion $x(t) = x_0 + \int_0^t \mu_{zt}dt + \int_0^t \sigma_z dB_{zt}$ and the two regulators $U(t)$ and $L(t)$: $z(t) = x(t) - U(t) + L(t)$. Now define a stopping time T_0 as the first date when $x(t) = \underline{z}$ with initial condition $x(0) = x_0 > \underline{z}$:

$$L(t) = \begin{cases} 0, & t \leq T_0, \text{ all } \omega \\ \underline{z} - \min_{s\in[0,t]} x(s), & t > T_0, \text{ all } \omega \end{cases}$$

Thus, $L(t)$ is continuous and non-decreasing, $L(0) = 0$, and only increases if $z(t) = \underline{z}$.

Now define a stopping time T_1 as the first date when $x(t) = 1$ with initial condition $x(0) = x_0 < 1$:

$$U(t) = \begin{cases} 0, & t \leq T_1, \text{ all } \omega \\ \max_{s\in[0,t]} x(s) - 1, & t > T_1, \text{ all } \omega \end{cases}$$

Thus, $U(t)$ is continuous and non-decreasing, $U(0) = 0$, and only increases if $z(t) = 1$.

Construction of the stochastic processes $U(t)$ and $L(t)$ for two boundaries $\underline{z} < 1$ with initial condition $x_0 \in [\underline{z}, 1]$ proceeds by induction, following Stokey (2009, p.202), and culminates in her Proposition 10.1 that states the regulated Brownian motion $z(t)$ is

$$z(t) = x(t) - U(t) + L(t), \text{ all } t,$$

where $L(t)$ and $U(t)$ are stochastic processes, and (L, U, z) have the following properties:

1. L and U are continuous and nondecreasing, with $L_0 = U_0 = 0$

2. $z(t)$ satisfies $z(t) \in [\underline{z}, 1]$, all t

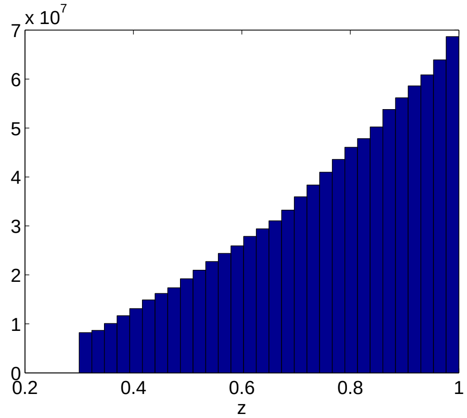
3. $L(t)$ only increases when $z(t) = \underline{z}$; $U(t)$, when $z(t) = 1$

An important fact is

$$\mathbb{E}[(dz)^2] = \mathbb{E}[(dx)^2] = \sigma_z^2 dt.$$

Because we specify the drift of the process to be non-constant ($\mu_z = \sigma_z^2/z$), a closed-form solution for the stationary density is unavailable. Instead, we bound a process from below by 0.3 and simulate a sample path of 100-million innovations and plot its histogram in Figure 11. The stationary density is tilted and has more mass near the upper boundary.

Figure 11: Histogram of simulated stationary density of relative productivity shock



Proof of Lemma 1. To show this, we fix an initial condition $z_0 \in [\underline{z}, 1]$ and define a localizing process of stopping times $0 = \tau_0 < \tau_1 < \tau_2 < \cdots \to \infty$ by

$$\tau_{n+1} = \min\{t > \tau_n | z(t) = z_0 \text{ and } z(s) = \underline{z} \text{ and } z(s') = 1, \text{ for some } \tau_n < s, s' < \tau_{n+1}\}.$$

Thus each stopping time is defined by having z_t reach each threshold, $\underline{z}$ and 1, and then to return to the initial condition z_0. Because of the boundedness of the process, each of these stopping times is finite with probability one and importantly

$$z_{\tau_n} = z_0, \text{ for all } n.$$

Because Ito's lemma for regulated processes holds for all t, we can choose $t = \tau_1$ so that $z_{\tau_1} = z_0$, and therefore an application of the lemma to the real exchange rate process S (and using $\mu_{zt} = \sigma_z^2/z_t)$ gives

$$\begin{aligned}0 &= -\int_0^{\tau_1} \frac{1}{\phi^* z^2}\left(\mu_z dt + \sigma_z dB_z + dL - dU\right) + \int_0^{\tau_1} \frac{1}{\phi^* z^3}\sigma_z^2 dt \\ &= -\frac{1}{\phi^* \underline{z}^2}\int_0^{\tau_1} dL + \frac{1}{\phi^*}\int_0^{\tau_1} dU - \int_0^{\tau_1} \frac{\sigma_z}{\phi^* z^2} dB_z,\end{aligned}$$

where the second equality uses the fact that dL is only positive when $z = \underline{z}$ and dU is only positive when $z = 1$. Taking expectations of this process conditional on our starting value for z gives

$$\frac{1}{\underline{z}^2}\mathbb{E}\left[\int_0^{\tau_1} dL \middle| S_0 = S(z_0)\right] = \mathbb{E}\left[\int_0^{\tau_1} dU \middle| S_0 = S(z_0)\right].$$

Because this equality holds for any arbitrary starting value within the boundaries, our expectation holds almost everywhere. Applying the conditional expectation operator to $\frac{dS}{S}$, given in (14) gives

$$\mathbb{E}_t\left[\frac{dS}{S}\right] = 0.$$

By definition, our localized process is a local martingale, and because the process is bounded it is a martingale. ∎

Proof of Lemma 2. Divide commodity exports (2.4) by z_c to get

$$\frac{x}{z_c} = p z_c \omega(z_c, z) + X + X\left(1 - \frac{\kappa X}{2 z_p}\right)\omega(z_c, z),$$

where we highlight $\omega(\cdot)$'s dependence on z_c. We bound this ratio above by 1 and rearrange the equation to get

$$\frac{1}{\kappa}\left(1 - \phi(z_c)\mathrm{z}\right)\left(1 + \frac{1}{2}\left(1 + \phi(z_c)\mathrm{z}\right)\left(\frac{\phi(z_c)}{\lambda}\mathrm{z}\right)^{-\frac{1}{\gamma}}\right) \leq z_c.$$

The left side of the equation is a function that depends on z and z_c. We first maximize the function with respect to z (by lowering z to $\underline{\mathrm{z}}$). We then define z_c^* as the maximum of the function, defining $H(z_c^*)$. Finally, we choose z_c on the right side to equal z_c^*. Thus $z_c^* = H(z_c^*)$. ∎

Proof of Lemma 3. From the commodity country's first-order conditions we get $y_{cp} = p(z_c -$

x). From our relationship in (3) we can write global output Y in units of the producer country's final good as $Y = y_p + y_{cp} \cdot S = z_p x + p(z_c - x)S = z_p z_c$; hence $dY = dz_p$. Simply using the dynamics of z_p and z_{cp} and calculating the covariances produces the result. ∎

Proof of Proposition 1. First, we define for convenience a function of z

$$s(z) \doteq \frac{\frac{1}{2\kappa}(1-\phi^* z)^2}{z_c \phi^* z + \frac{1}{2\kappa}(1-\phi^* z)^2},$$

and the risk premium function

$$\varphi(z) \doteq \gamma \sigma_z^2 \frac{1}{z^2} \left[s(z) \frac{(1+\phi^* z)}{1-\phi^* z} - \frac{1-\frac{1}{\gamma}}{1+\phi^* z \omega(z)} \right].$$

Positivity of risk premium

In the case of log utility the risk premium function φ becomes

$$\varphi(z) = \sigma_z^2 \frac{1}{z^2} s(z) \frac{(1+\phi^* z)}{1-\phi^* z}. \qquad \text{(A-5)}$$

We set z_c high enough such that $\phi^* < 1$ so that $s(z)$ is always positive. The risk premium, additionally, is also always positive.

Positivity of interest rate differential

To see that the interest rate differential is positive, note that since the real exchange rate process is a martingale, the interest-rate differential equals the risk premium and therefore under the same condition on ϕ^* is (almost surely) positive.

Import ratio

Even though in our model the trade cost is a pure dead weight loss, in order to be consistent with the available measures of imports and exports in our empirical work we define the import ratios omitting the losses due to trade costs and specify them as

$$IR_c \doteq \frac{XS + xpS}{y_{cp}S} \tag{A-6}$$

$$IR_p \doteq -\left(\frac{X + xpS}{y_p}\right) \tag{A-7}$$

$$\Delta IR \doteq IR_c - IR_p = \frac{\frac{1}{\kappa}(\frac{1}{\phi^* z} - 1) + x}{z_c - x} + \frac{(1 - \phi^* z)\frac{1}{\kappa} + x}{x}. \tag{A-8}$$

Under log utility, the quantity of commodity exports becomes

$$x = \frac{\lambda}{1+\lambda} z_c + \frac{1}{1+\lambda}\frac{X}{z_p}\left(1 + (1 - \tau(X, z_k))\frac{\lambda}{\phi^* z}\right) \tag{A-9}$$

$$= \frac{\lambda}{1+\lambda}\left[z_c + \frac{X}{z_p}\frac{1}{\lambda} + \frac{X}{z_p}(1 - \tau(X, z_k))\frac{\lambda}{\phi^* z}\right] \tag{A-10}$$

and it is easy to see that

$$\frac{\partial x}{\partial z} = -\frac{\lambda}{1+\lambda}\left(\frac{\phi^*}{\kappa\lambda} + \frac{1}{2\kappa}\left(\frac{1}{\phi^* z^2} + \phi^*\right)\right) < 0 \tag{A-11}$$

So differentiating (A-8) gives

$$\frac{\partial \Delta IR}{\partial z} = \frac{\left(-\frac{1}{\phi^* z^2 \kappa} + \frac{\partial x}{\partial z}\right)(z_c - x) + \left(\left(\frac{1}{\phi^* z} - 1\right)\frac{1}{\kappa} + x\right)\frac{\partial x}{\partial z}}{(z_c - x)^2} + \frac{\left(-\frac{\phi^*}{\kappa} + \frac{\partial x}{\partial z}\right)x - \left((1 - \phi^* z)\frac{1}{\kappa} + x\right)\frac{\partial x}{\partial z}}{x^2} \tag{A-12}$$

$$= \frac{-\frac{1}{\phi^* z^2 \kappa}(z_c - x) + \frac{\partial x}{\partial z} z_c + \left(\frac{1}{\phi^* z} - 1\right)\frac{1}{\kappa}\frac{\partial x}{\partial z}}{(z_c - x)^2} - \frac{\frac{\phi^*}{\kappa}x + (1 - \phi^* z)\frac{1}{\kappa}\frac{\partial x}{\partial z}}{x^2}, \tag{A-13}$$

which we need to be less than zero. There are two cases in which it is: (i) $x^2 \geq (z_c - x)^2$ and (ii) $x^2 < (z_c - x)$. The first case is trivially satisfied because $\frac{1}{\phi^* z} - 1 > 1 - \phi^* z \Leftrightarrow (1 - \phi^* z)^2 \geq 0$. The second case requires making z_c "large enough", requiring the following condition to hold:

$$z_c + \left(\frac{1}{\phi^* z} - 1\right)\frac{1}{\kappa}\left(\frac{x}{z_c - x}\right)^2 > (1 - \phi^* z)\frac{1}{\kappa}, \tag{A-14}$$

which is an easier condition to satisfy than

$$z_c > (1 - \phi^* \underline{z})\frac{1}{\kappa}, \tag{A-15}$$

which is required by Lemma 2 and thus holds given our choice of $z_c > z_c^*$. The difference in import ratios, therefore, is monotonically decreasing in z.

Monotonicity in z of risk premium and interest rate differential

To show monotonicity, we differentiate the risk premium function with respect to z:

$$\varphi'(z) = \sigma_z^2 \left(-2\frac{1}{z^3} s(z) \frac{1+\phi^* z}{1-\phi^* z} + \frac{1}{z^2} \left(\frac{s'(z)(1+\phi^* z)(1-\phi^* z) + 2\phi^* s(z)}{(1-\phi^* z)^2} \right) \right) \tag{A-16}$$

$$= \sigma_z^2 \left(\frac{1}{z^2} s'(z) \frac{1+\phi^* z}{1-\phi^* z} - 2\frac{s(z)}{z^3(1-\phi^* z)^2}(1 - \phi^* z(1+\phi^* z)) \right) < 0 \tag{A-17}$$

Because $s'(z) < 0$, This last equation holds if $1 - \phi^* z - (\phi^* z)^2 > 0$, or equivalently requiring $1 > \max_{z \in [\underline{z}, 1]} z\phi^* + z^2(\phi^*)^2 = \phi^* + (\phi^*)^2$ or equivalently $z_c > \left(\frac{2}{\sqrt{5}-1}\alpha^\alpha(1-\alpha)^{1-\alpha}\right)^{\frac{1}{1-\alpha}} \doteq F(\alpha)$, by plugging in the equation for ϕ^* and rearranging terms. This last function $F(\alpha)$ has a maximum of $\frac{2}{\sqrt{5}-1}$ on $\alpha \in [0, 0.8651)$, so we restrict our choice of α to that interval and set $z_c > \max\{\frac{2}{\sqrt{5}-1}, z_c^*\}$. The choice of exporting the commodity is partially determined by the curvature of the commodity-producing production function of the commodity country as well as the nonlinear dynamics of the exchange rate. The second-order term $(\phi^* z)^2$ shows up (and thus $1 - \phi^* z > 0$ doesn't always hold) because the equilibrium specification needs to (lightly) restrict the curvature of this export choice to variation in z.

Because the growth of the real exchange rate $\frac{dS}{S}$ follows a martingale, the monotonicity of the risk premium function also implies that the interest rate differential is monotone in z as well.

∎

Cross-sectional asset pricing methodology

Let Rx_{t+1}^i to denote the average excess return in levels on portfolio i in period $t+1$. All asset pricing tests are run on excess returns in levels, not log excess returns, to avoid having to assume joint log-normality of returns and the pricing kernel. In the absence of arbitrage opportunities, this excess return has a zero price and satisfies the following Euler equation:

$$E_t[M_{t+1}Rx^i_{t+1}] = 0.$$

We assume that the stochastic discount factor M is linear in the pricing factors f:

$$M_{t+1} = 1 - b(f_{t+1} - \mu_f),$$

where b is the vector of factor loadings and μ_f denotes the factor means. This linear factor model implies a beta pricing model: the expected excess return is equal to the factor price λ times the beta of each portfolio β^i:

$$E[Rx^i] = \lambda' \beta^i,$$

where $\lambda = \Sigma_{ff} b$, $\Sigma_{ff} = E(f_t - \mu_f)(f_t - \mu_f)'$ is the variance-covariance matrix of the factor, and β^i denotes the regression coefficients of the return Rx^i on the factors. To estimate the factor prices λ and the portfolio betas β, we use two different procedures: a Generalized Method of Moments estimation (GMM) applied to linear factor models, following Hansen (1982), and a two-stage OLS estimation following Fama and MacBeth (1973), henceforth FMB. In the first step, we run a time series regression of returns on the factors. In the second step, we run a cross-sectional regression of average returns on the betas (without a cross-sectional intercept), period by period, averaging the slope coefficients to obtain estimates of λ.

Data Appendix

This appendix describes the details of data construction and the robustness of empirical results.

4.1 Pairwise Returns

To show that the trading strategies are both unconditional in nature, and not driven by any one currency pair, we present the returns of currency pairs for each combination of short a final good producer currency and long a commodity country currency, as well as portfolios of all commodity countries or all producer countries. Table A-1 shows the results.

4.2 Classification of goods

We assign individual goods to "Basic" (input) and "Complex" (finished) groups based on the descriptions of 4-digit SITC (Revision 4) categories available from the U.N. Table A-2 lists classifications aggregated at a 2-digit SITC level, with the number of 4-digit sub-categories falling into each of the two groups. A detailed breakdown is available upon request.

4.3 Currency strategies and transaction costs

We investigate the effect of transaction costs on the profitability of trading strategies based on the combined export/import sort. We use bid-ask quotes for forward and spot exchange rates from Reuters. Lyons (2001) reports that bid and ask quotes published by Reuters imply bid-ask spreads that are approximately twice as large as actual inter-dealer spreads. We assume that net excess returns take place at these quotes. As a result, our estimates of the transaction costs are conservative, at least from the standpoint of a large financial institution. Since our strategy is based on sorting currencies using trade data that is available at annual frequency, a natural approach for minimizing the transaction costs is to use one-year forward contracts. Therefore, we compute returns on rolling one-year forward contracts, but in order to avoid the arbitrary choice of the starting month, we construct the portfolio returns at monthly frequency (i.e., using overlapping yearly returns). Table A-3 lists the average depreciation of

Table A-1: Pairwise Currency Strategy Returns

Long Leg		**Short Leg**				
		Europe / Germany	Japan	Sweden	Switzer-land	Producer Country Portfolio
Australia	Return	3.90	5.22*	3.20	4.25	4.14*
	SE	(2.41)	(3.10)	(2.34)	(2.68)	(2.33)
	SR	0.09	0.10	0.08	0.09	0.10
Canada	Return	1.82	3.14	1.12	2.17	2.06
	SE	(2.21)	(2.71)	(2.16)	(2.47)	(2.04)
	SR	0.05	0.07	0.03	0.05	0.06
Norway	Return	2.14*	3.46	1.44	2.49	2.38*
	SE	(1.23)	(2.66)	(1.36)	(1.62)	(1.31)
	SR	0.10	0.07	0.06	0.09	0.11
New Zealand	Return	3.77*	5.09*	3.07	4.12*	4.01*
	SE	(2.18)	(2.89)	(2.22)	(2.35)	(2.08)
	SR	0.10	0.10	0.08	0.10	0.11
Commodity Country Portfolio	Return	2.91*	4.22	2.21	3.26*	3.15**
	SE	(1.64)	(2.56)	(1.64)	(1.96)	(1.54)
	SR	0.10	0.10	0.08	0.10	0.12

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Excess mean returns and Sharpe ratios on pairwise and portfolio trading strategies for G10 commodity and final producer currencies. Returns are calculated using monthly forward returns for a strategy going long a commodity country currency of Australia, Canada, Norway, and New Zealand (or an equal weighted portfolio of all four), and short a producer country currency of Europe (or the German Deutschmark Pre-1999), Japan, Sweden, and Switzerland (or an equal weighted porftolio). White (1980) standard errors in parentheses. Data is 1988 to 2012, and returns do not include transaction costs.

Table A-2: COMTRADE Goods Classification

SITC	Description	Sub-categories classified as Basic	Complex
00	Live animals	13	2
01	Meat and meat preparations	14	0
02	Dairy products and eggs	10	0
03	Fish and fish preparations	12	0
04	Cereals and cereal preparations	24	0
05	Fruit and vegetables	25	1
06	Sugar, sugar preparations and honey	4	4
07	Coffee, tea, cocoa, spices and manufacs. thereof	10	5
08	Feed. Stuff for animals excl. Unmilled cereals	6	0
09	Miscellaneous food preparations	5	0
11	Beverages	0	7
12	Tobacco and tobacco manufactures	4	4
21	Hides, skins and fur skins, undressed	9	0
22	Oil seeds, oil nuts and oil kernels	14	0
23	Crude rubber including synthetic and reclaimed	5	0
24	Wood, lumber and cork	14	0
25	Pulp and paper	0	7
26	Textile fibres, not manufactured, and waste	32	0
27	Crude fertilizers and crude minerals, nes	23	0
28	Metalliferous ores and metal scrap	22	0
29	Crude animal and vegetable materials, nes	11	0
32	Coal, coke and briquettes	8	0
33	Petroleum and petroleum products	2	11
34	Gas, natural and manufactured	0	4
35	Electric energy	0	2
41	Animal oils and fats	3	0
42	Fixed vegetable oils and fats	14	0
43	Animal and vegetable oils and fats, processed	5	0
51	Chemical elements and compounds	0	28
52	Crude chemicals from coal, petroleum and gas	0	14
53	Dyeing, tanning and colouring materials	0	11
54	Medicinal and pharmaceutical products	0	8
55	Perfume materials, toilet and cleansing preptions	0	9
56	Fertilizers, manufactured	0	5
57	Explosives and pyrotechnic products	0	4
58	Plastic materials, etc.	0	28
59	Chemical materials and products, nes	0	13
61	Leather, lthr. Manufs., nes and dressed fur skins	9	5
62	Rubber manufactures, nes	2	10
63	Wood and cork manufactures excluding furniture	2	12
64	Paper, paperboard and manufactures thereof	0	15
65	Textile yarn, fabrics, made up articles, etc.	0	58
66	Non metallic mineral manufactures, nes	0	39
67	Iron and steel	8	26
68	Non ferrous metals	26	0
69	Manufactures of metal, nes	0	32
71	Machinery, other than electric	0	25
72	Electrical machinery, apparatus and appliances	0	36
73	Transport equipment	0	10
81	Sanitary, plumbing, heating and lighting fixt.	0	4
82	Furniture	0	4
83	Travel goods, handbags and similar articles	0	2
84	Clothing	0	35
85	Footwear	0	2
89	Miscellaneous manufactured articles, nes	0	39
94	Animals, nes, incl. Zoo animals, dogs and cats	2	0
95	Firearms of war and ammunition therefor	0	2

Each row represents a 2-digit Standard International Trade Classification category according to SITC Rev. 4. The classification columns show the number of 4-digit sub-categories classified as each type of good (Basic or Complex). Descriptions are from the United Nations Statistics Division.

the currencies in each portfolio, average (log) forward discount, and average excess returns with and without bid-ask spreads applied.

4.4 Cross-Sectional Regressions

One concern for cross-sectional empirical tests of forward discounts and returns on the various predictor variables is the high degree of persistence in both the independent and dependent variables of the Fama-Macbeth regressions shown in Table 2 in the text. While the regressions attempt to control for serial correlation of the error terms by using Newey-West standard errors, here we take the more aggressive approach of estimating panel regressions using a between-effects specification, which is equivalent to estimating regressions of unconditional country means of forward discounts and FX returns on unconditional means of the predictor variables. Table A-4 shows the results. This specification ignores all information in the time series, and therefore has less power than the specification presented in the text, however we still find a strong relation between the Import Ratio measures and both forward discounts and returns.

4.5 Relative Exchange and Interest Rates vs. Manufacturing Output

A primary implication of the model is that the relative productivity levels in the complex goods sector drive the real exchange rate and the interest rate differential of the two countries. In the main text, we proxy for this level of productivity using aggregate economic labor productivity for the two economies. Here we report regressions using quarterly changes in the quantity index of “Production in total manufacturing” reported by the OECD. Tables A-5 and A-6 show the results for exchange rates and interest rates respectively. As the tables show, the results with this proxy again provide support for the model mechanism, and are if anything stronger than the results using aggregate productivity.

Table A-3: One-Year Returns on Import/Export Sorted Portfolios, All Countries

Portfolio	1	2	3	4	5	6
			Spot Change: Δs^j (without b-a)			
Mean	0.08	−0.37	−1.03	0.37	1.33	−0.50
Std	6.77	9.90	9.36	8.87	9.19	9.14
			Forward Discount: $f^j - s^j$			
Mean	−0.48	1.29	1.15	1.99	2.19	2.23
Std	1.87	2.19	2.39	2.29	1.32	1.63
			Log Excess Return: rx^j (without b-a)			
Mean	−0.56	1.66	2.18	1.61	0.86	2.73
Std	7.29	9.93	9.15	8.99	9.45	9.18
SR	−0.08	0.17	0.24	0.18	0.09	0.30
			Excess Return: rx^j (without b-a)			
Mean	0.01	2.32	2.80	2.29	1.62	3.38
Std	7.09	9.93	9.42	8.87	9.80	9.39
SR	0.00	0.23	0.30	0.26	0.17	0.36
			Net Excess Return: rx^j_{net} (with b-a)			
Mean	0.27	2.07	2.61	2.08	1.40	3.17
Std	7.16	9.93	9.39	8.84	9.78	9.38
SR	0.04	0.21	0.28	0.24	0.14	0.34
			High-minus-Low: rx^j_{net} (without b-a)			
Mean		2.31	2.79	2.28	1.61	3.37
Std		6.57	6.58	5.93	7.59	6.96
SR		0.35	0.42	0.38	0.21	0.48
			High-minus-Low: $rx^j_{net} - rx^1_{net}$ (with b-a)			
Mean		1.80	2.34	1.81	1.13	2.90
Std		6.58	6.58	5.95	7.60	6.92
SR		0.27	0.36	0.30	0.15	0.42

Note: Portfolios are rebalanced annually. Reported returns are sampled monthly with overlap. Sample is 1/1988-12/2012.

Table A-4: Cross-Sectional Regressions of FX Returns and Forward Discounts: Between Effects

Panel A: IMF Advanced Economies

	Fama-Macbeth Regressions of FX Returns					Panel Regressions of FX Discounts				
VARIABLES	FX Ret	FX Ret	FX Ret	FX Ret	FX Ret	FX Dsct	FX Dsct	FX Dsct	FX Dsct	FX Dsct
IMX Ratio	0.30*		0.36**	0.27*	0.32**	0.23+		0.24+	0.14*	0.17**
	(0.11)		(0.11)	(0.11)	(0.10)	(0.11)		(0.12)	(0.05)	(0.05)
Log GDP		0.19	0.46		0.53+		-0.12	0.06		0.21
		(0.33)	(0.29)		(0.26)		(0.31)	(0.31)		(0.14)
Inflation				0.16+	0.17*				0.36**	0.36**
				(0.08)	(0.08)				(0.04)	(0.04)
Observations	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350
R-squared	0.26	0.01	0.34	0.37	0.48	0.16	0.01	0.16	0.82	0.83
Periods	304	304	304	304	304	304	304	304	304	304

Panel B: G10 Currencies

	Fama-Macbeth Regressions of FX Returns					Panel Regressions of FX Discounts				
VARIABLES	FX Ret	FX Ret	FX Ret	FX Ret	FX Ret	FX Dsct	FX Dsct	FX Dsct	FX Dsct	FX Dsct
IMX Ratio	0.26**		0.18*	0.18*	0.12	0.24*		0.20+	0.07	0.06
	(0.06)		(0.07)	(0.07)	(0.07)	(0.08)		(0.10)	(0.05)	(0.06)
Log GDP		-0.77**	-0.42+		-0.37		-0.59+	-0.21		-0.10
		(0.22)	(0.22)		(0.20)		(0.28)	(0.31)		(0.17)
Inflation				0.25	0.22				0.50**	0.49**
				(0.14)	(0.13)				(0.10)	(0.10)
Observations	2,927	2,927	2,927	2,927	2,927	2,927	2,927	2,927	2,927	2,927
R-squared	0.17	0.14	0.25	0.31	0.40	0.54	0.41	0.59	0.97	0.97
Periods	304	304	304	304	304	304	304	304	304	304

Standard errors in parentheses
** $p<0.01$, * $p<0.05$, + $p<0.1$

This table shows cross-sectional regressions of FX returns and forward discounts on the Import ratio as well as log of GDP and lagged 3-year inflation. Regressions are monthly using the previous calendar year's values of the independent variables. Panel regressions are calculated using between time and country effects. Data are monthly from 1988 to 2012.

Table A-5: Real Exchange Rates and Relative Manufacturing Output: G10 Countries

Panel A: Innovations

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$
$\Delta RER_{t,t+1}$	0.069*	0.303**	0.151**	0.338**	0.059	0.307+	0.118*	0.244+
	(0.032)	(0.106)	(0.038)	(0.068)	(0.081)	(0.171)	(0.057)	(0.129)
Constant	-0.002	-0.005	-0.001	-0.002	0.000	-0.001	-0.003	-0.006
	(0.003)	(0.004)	(0.002)	(0.003)	(0.002)	(0.004)	(0.003)	(0.005)
Obs.	104	103	104	103	104	103	104	103
R^2	0.025	0.187	0.114	0.211	0.011	0.130	0.052	0.111

Panel B: Levels

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t
RER_t	-0.163	0.165**	0.115	0.401**	0.159+	0.154	-0.190	0.140*
	(0.109)	(0.054)	(0.126)	(0.105)	(0.095)	(0.134)	(0.126)	(0.068)
Trend		-0.004**		-0.004**		0.000		-0.004**
		(0.000)		(0.001)		(0.001)		(0.001)
Constant	0.798+	-0.320	-0.288	-0.654**	-0.044	-0.045	0.845+	-0.225
	(0.455)	(0.212)	(0.264)	(0.191)	(0.030)	(0.037)	(0.506)	(0.255)
Obs.	105	105	105	105	105	105	105	105
R^2	0.108	0.792	0.051	0.548	0.128	0.128	0.109	0.766

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.10

Table shows regressions of relative manufacturing output (RM_t) against real exchange rates (RER_t). Each commodity country's real exchange rate and relative productivity are calculated with respect to an equal weighted basket of its primary trading partners among the producer countries. Germany's exchange rate is calculated using the Euro post 1999. All exchange rates are converted to real using the relative value of country CPI. Relative manufacturing output is calculated as the log-difference of real manufacturing output from the OECD. Data are quarterly. Newey-West standard errors with 8 lags are shown in parentheses.

Table A-6: Real Interest Rate Differentials and Relative Manufacturing Output: G10 Countries

Panel A: Innovations

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$	$\Delta RM_{t,t+1}$
$\Delta RIR_{t,t+1}$	2.668+	4.154+	0.282	-0.829	0.641	1.229	1.615	4.396**
	(1.361)	(2.281)	(1.241)	(2.371)	(0.990)	(2.017)	(1.457)	(1.544)
Constant	-0.002	-0.005	-0.001	-0.000	0.001	0.000	-0.002	-0.005
	(0.003)	(0.005)	(0.002)	(0.004)	(0.002)	(0.004)	(0.003)	(0.005)
Obs.	104	103	104	103	104	103	104	103
R^2	0.041	0.042	0.001	0.002	0.005	0.007	0.022	0.061

Panel B: Levels

	Aus vs. Jap		Can vs. Ger, Jap		Nor vs Ger, Jap, Swe		NZ vs Jap	
	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t	RM_t
RIR_t	11.269*	6.576**	20.469**	15.947*	3.188	6.676+	14.691**	5.569+
	(4.486)	(2.068)	(7.291)	(6.793)	(3.970)	(3.517)	(4.984)	(2.870)
Trend		-0.003**		-0.001		0.001*		-0.003**
		(0.000)		(0.001)		(0.001)		(0.001)
Constant	0.144**	0.319**	-0.034	0.046	-0.001	-0.071*	0.093**	0.285**
	(0.027)	(0.023)	(0.028)	(0.058)	(0.018)	(0.036)	(0.027)	(0.033)
Obs.	105	105	105	105	105	105	105	105
R^2	0.202	0.791	0.218	0.316	0.023	0.211	0.249	0.742

Standard errors in parentheses
** p<0.01, * p<0.05, + p<0.10

Table shows regressions of relative manufacturing output (RM_t) on real interest rate differentials (RIR_t) . Each commodity country's real interest rate differential and relative productivity are calculated with respect to an equal weighted basket of its primary trading partners among the producer countries. Germany's interest rate is calculated using the Euro post 1999. All nominal interest rates are converted to real by adjusting for predicted inflation calculated as a four quarter moving average of CPI growth centered at the observation. Relative manufacturing output is calculated as the log-difference of real manufacturing outputs from the OECD. Data are quarterly. Newey-West standard errors with 8 lags are shown in parentheses.